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Editor, ALFRED J. HENRY

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THE LONG DRY SEASON OF 1929 IN THE FAR WEST

By Edward H. Bowie

[Weather Bureau Office, San Francisco, Calif., December 24, 1929]

The normal régime of annual meteorological sequences on the west coast comprehends a season of little or no rain from late spring until early autumn, and a season of rains which on the average begins during the month of September, reaches its maximum in point of frequency in midwinter, and ends in the month of May.

The dry season is shorter and the wet season correspondingly longer on the north than on the south coast. On the coast proper the annual precipitation increases from approximately 10 inches in the vicinity of San Diego on the California coast, a short distance north of the Mexican border, to over 100 inches on the Washington coast, and farther north to nearly 300 inches on the west coast of Vancouver Island, British Columbia.[1] It is interesting to note in passing that of all parts of North America for which there are authentic records, this point, Henderson Lake, on the western coast of Vancouver Island, British Columbia, has the greatest annual precipitation.

Latitude, seemingly, is the most important control in determining the annual precipitation on the west coast. There can be no question, however, that topography is scarcely less important than latitude in determining rainfall here as elsewhere. We find, for example, local areas in southern California inclosed by high mountain ranges with the annual precipitation is less than 5 inches, and where at times one or more years may pass without the occurrence of measurable amounts of precipitation; and, again, on Vancouver Island where occurs the heaviest known rainfall of the North American Continent (approximately 300 inches), there are places where the annual precipitation is less than 20 inches, so great is the topographic effect of mountain ranges between them and the Pacific Ocean. It is interesting to observe that the latitudinal control on the west coast works oppositely to the way it does on the east coast where the greatest annual precipitation occurs in Florida and the least in Maine.

The fact that the greatest of all evaporating surfaces, the Pacific Ocean, lies adjacent to the region under consideration, might lead one to infer that the west coast would have necessarily well distributed rains in all months of the year, and that its latitudinal distribution of precipitation would be opposite to what it actually is. To reach this conclusion, however, one must ignore the fact that the evaporation goes on from an ocean surface which is materially cooler in summer than the land surface, and that consequently the air over the ocean, in passing onto the land, has its temperature materially raised, its relative humidity correspondingly reduced, and the occurrence of rain made difficult; while in the winter months, when the land surface is cooler than the ocean surface, air moving from the latter over the former has its temperature reduced, its relative humidity raised, and the condensation of its water vapor made more or less easy. It is apropos here to state the inescapable conclusion that forests can have little effect on precipitation in the Pacific Coast States, for it is during the period when forest trees are dormant that the rainy season occurs, and during the season when forest trees are transpiring moisture that there is little or no rainfall.

Furthermore, without a knowledge of the seasonal distribution of air pressure and resulting winds over the northeast Pacific Ocean and on the west coast, quite faulty ideas may well be drawn in respect to the frequency, occurrence, and travel of the important precipitation causes, namely, cyclones, of the northeast Pacific Ocean and the west coast of North America. There is no question in the mind of the writer that as the major areas of high barometric pressure with their accompanying systems of free air winds change their positions, shapes, and magnitudes, the frequency of occurrence, intensities, and paths of travel of cyclones change correspondingly. Thus, over the northeast Pacific Ocean in the summer season, i. e., the rainless season of the west coast, the barometer stands high and the system of winds is distinctly anticyclonic over the northeast Pacific Ocean. At this season of the year practically all of the cyclones of the north Pacific Ocean form over tropical waters of that ocean or pass onto it from high latitudes of the Asiatic Continent. Many of these cyclones, other than those which form off the west coast of Mexico, attempt the passage of the north Pacific Ocean in high latitudes, but few of them reach the coast of North America south of Alaska. The Bering Sea and the Bay of Alaska appear to be the graveyards of nearly all of the summer storms that attempt the crossing of the north Pacific Ocean. The area of high barometric pressure off the west coast in the summer season is an effective barrier in preventing cyclones of that season of the north Pacific Ocean from reaching our west coast. Moreover, the air coming from the ocean onto the continent, while of high humidity but low temperature, on reaching the land is heated by radiation from the surface and has its relative humidity greatly lowered, thus making precipitation impossible. During the dry season such rains as do occur are usually associated with the movement of surfaces of discontinuity or faults eastward from the coast, are local as a rule, and generally accompany thunderstorms, particularly over the mountain districts of the interior States.

[1] In 1928, Henderson Lake, Vancouver Island, British Columbia, reported 281.44 inches of precipitation.

As the warm season wanes and the fall comes on, a change in barometric pressure distribution over the ocean as well as the continent sets in unless some unusual cause operates to prevent it. As the fall passes, the area of high barometric pressure normally centered midway between the Oregon coast and Hawaiian Islands loses in geographical magnitude, shows lower barometric readings over the area occupied, and its center retreats southward well beyond the point where it is normally found in midsummer. At the same time the barometer falls over the Gulf of Alaska, the Bering Sea, the Aleutian Islands, and thence southwestward over the ocean to Japan in which areas frequent traveling cyclones form and move eastward along the northern periphery of the anticyclone, bringing the Pacific Northwestern States under their influence and causing the dry season to end. If at any time when one of these cyclones is traveling eastward over the Pacific Ocean the more or less permanent anticyclone to the southward is well south of its normal position, the track of the cyclone to the northward will be correspondingly south of its most frequented track, provided the barometer is high over the Alaskan area and the Bering Sea. Under these conditions early fall rains are likely to occur as far south as southern California, terminating the dry season as far south as the Mexican border. The only other condition likely to terminate the dry season in southern California comes when a cyclone of tropical origin moves northwestward, its track paralleling the west coast of Mexico, and brings the southern part of California under its influence. At rather infrequent intervals such cyclones reach southern California in August or September, and when they do heavy local rains fall; but rarely do they occur north of the Tehachapi Mountains, which range lies across the State to the northward of the Los Angeles area.

As previously stated, any cause that operates to prolong the summer high pressure over the north Pacific Ocean tends to prolong the dry season in the far Western States. What the cause or causes are, other than unusual temperature distribution over continent and ocean, that prolong the dry season type of pressure distribution, it is difficult to visualize; but that it or they operated to prolong the dry season through the fall months and into December of 1929, is clearly shown by the records of precipitation during the period to which this article refers. Moreover, the cause or causes must have been operative over a large geographical area to have produced what is generally regarded as the longest dry season of record over an area as large as that of the far West.

The following table gives comparative precipitation data at stations in the far Western States for July to November inclusive. The first column in this table gives the seasonal catch of precipitation during July to November, 1929, inclusive; the second column, the normal or average precipitation July to November inclusive; the third column the least amount of precipitation in these months prior to 1929; and the fourth the year when it was recorded. A fifth column gives the year when the record began.

Table showing comparative precipitation for stations in the far Western States for the period July to November, inclusive

Station	Seasonal, July to November, 1929, inches	Normal, July to November, inches	Least seasonal, July to November		Record began, year
			Inches	Year	
Seattle, Wash	3.58	10.97	3.56	1895	1891
Tacoma, Wash	2.47	13.02	5.63	1917	1878
Spokane, Wash	0.85	5.47	1.37	1917	1881
Tatoosh Island, Wash	15.46	27.82	15.13	1923	1884
North Head, Wash	4.83	18.19	8.96	1917	1878
Portland, Oreg	2.56	12.45	4.11	1890	1871
Walla Walla, Wash	1.73	5.32	1.37	1890	1886
Lewiston, Idaho	1.22	4.81	1.06	1890	1878
Boise, Idaho	0.63	3.39	0.06	1868	1868
Pocatello, Idaho	3.56	4.56	2.00	1902	1899
Baker, Oreg	0.82	3.77	1.23	1892	1889
Winnemucca, Nev	0.14	2.12	0.12	1880	1877
Reno, Nev	0.69	1.73	0.38	1915	1888
Eureka, Calif	0.22	8.81	1.00	1880	1878
Red Bluff, Calif	0.10	5.18	0.22	1880	1877
Sacramento, Calif	0.15	3.18	T.	1850	1850
San Francisco, Calif	0.01	3.95	0.33	1890	1849
San Jose, Calif	T.	2.53	0.10	1890	1874
Fresno, Calif	0.01	1.73	0.19	1893	1881
Los Angeles, Calif	0.32	2.08	0.06	1891	1877
San Diego, Calif	0.26	1.45	0.05	1894	1850

The situations arising from the delayed ending of the dry season of 1929 were distressing in many sections of the far West, but while serious they were not unduly alarming. Nevertheless, water became scarce in many sections for domestic purposes, for stock, for irrigation, and for hydroelectric power and lighting, except where supplies for long periods had been impounded. There was delay in the seeding and planting of fall crops and there was no pasturage in California for stock and hence feeding became general in November. The public mind was greatly concerned lest the usual winter rains might not occur, and no doubt the lengthened dry season to a considerable degree affected plans for outlays of credit and budgeting of funds for many purposes. This state of mind changed as soon as the rainy season started in the second week of December.

An examination of the weather charts for the fall months of 1929 shows a number of anomalies, but what they might be attributed to can not be stated with precision. Apparently observations from a much larger area than that now covered are necessary to determine the physical processes that underlie such radical departures from normal or average conditions. Moreover, much effort and skill will be required to interpret such data and state the true explanations of abnormalities of this order. It is quite certain that their first causes will not be made known by chance or through revelation. The most obvious of the anomalies were:

1. The continuation through September and October of high or relatively high barometric pressure over the north Pacific Ocean in latitudes where ordinarily found only in the summer season, and at the same time low barometric pressure over the Bering Sea, the north portion of the Gulf of Alaska, and along and south of the Aleutian Islands.

2. In November extraordinarily high barometric pressure was general along and off the western coast, over the Plateau region and western Canada.

3. During the early fall months the upper air winds reported by pilot balloon stations showed normal summer conditions, i. e., variable but mostly southwest at high altitudes over the far Western States.

4. In November the winds over the far Western States up to high altitudes were prevailingly from the north [1] as shown by pilot-balloon runs, whereas normally they would be changeable between southwest and northwest.

5. Over the ocean in November the barometer stood high over and off our western coast to a considerable distance, but over midocean and the Bering Sea it stood low with numerous cyclones forming and moving north or northeastward to the Bering Sea and the Bay of Alaska. No one of these of importance reached the coast of North America south of Vancouver Island.

6. It would appear that the September and October cyclones of the north Pacific Ocean were unable to penetrate the high barometric pressure and its system of winds; instead they moved along the northern periphery of the high pressure area in high latitudes.

7. The high barometric pressure along and off our western coast during November was an effective barrier to the eastward advance of many cyclones that made their appearance over midocean and moved to the Bering Sea where they disappeared beyond our field of observations.

8. The northerly winds prevailing up to high altitudes over the far Western States would account for the scarcity of precipitation in that region during November. This occurrence was associated with the high barometric pressure referred to in 2, and it, no doubt, occurred in response to temperature abnormalities over a large area. It will be recalled that with the trial forecast of the seasonal rainfall for southern California for the winter of 1929-30, issued by the Scripps Institution of Oceanography, the statement was made that the water temperatures off La Jolla, Calif., during the summer of 1929, were the highest recorded since observations began there. If high water temperatures prevailed over a considerable area of the ocean off the western coast of Mexico through the fall of 1929, and that seems altogether possible, we should have an explanation of the prevalent north winds over the far Western States during November.

9. Reference is made in 5 to the occurrence of cyclones over midocean and to their passing north and northeastward. It seems likely that west of the current of northerly winds prevailing in that month along our western coast, there must have been a countercurrent, a south wind, along which these midocean cyclones traveled to the Bering Sea. It is also possible that this south current accounted for the high temperatures in the interior of Alaska in that month.

10. The pressure rose decidedly in the early part of December over the Bering Sea and the western parts of Alaska, forming an area of high barometric pressure that extended thence eastward over Canada, and at the same time pressure gradually fell off our west coast and over that part of the ocean thence westward to and beyond the Hawaiian Islands. At the same time the northerly winds of the Western States gave way and became southerly and westerly. With this readjustment of the pressure situation over the northeast Pacific Ocean, the Bering Sea and the adjacent areas of the North American Continent, cyclones formed over the middle latitudes of the north Pacific Ocean and traveled toward the west coast, so that during the second week of December the dry season had ended generally in the far Western States except in southern California.[2]

The several distributions of barometric pressure with their associated wind systems, to be referred, of course, to the temperature distribution over large areas, are unquestionably what brought about the prolonged dry season in the far Western States in 1929.

It will be noted in paragraph 1 that the pressure distribution during the fall up to and including October of 1929 was such as to prevent the approach of cyclones to our coast south of latitude 50°; and that in numbered paragraph 2 reference is made to high barometric pressure and northerly winds along and off our western coast, which the cyclones over the ocean to the west could not penetrate. These cyclones were carried northward to the Bering Sea by a countercurrent, a south current, presumably of great width and considerable depth over midocean. It will be noted further that when the pressure rose in high latitudes, notably the Bering Sea and western Alaska, and decreased over the northeast Pacific Ocean (see par. 10) the dry-season soon came to an end, i. e., during the second week of December, except in Southern California.

[1] In the Pacific States north winds are dry and hot in summer and dry and cold in winter.—*E. H. B.*

[2] The dry season continued in southern California through December.

WEATHER AND COTTON YIELD IN TEXAS, 1899-1929, INCLUSIVE

By LAWRENCE H. DAINGERFIELD

[Weather Bureau Office, Houston, Tex.]

The tropical origin of cotton is easily demonstrated by its tolerance of heat and marked intolerance of cold. While it generally is safe to sow wheat when the average daily air temperature reaches 37° to 38° and oats at 42° to 44°, and plant corn at 55°, cottonseed should not go in the ground until the mean warmth reaches 62°, according to trustworthy authorities. Thus the planting period in Texas during a normal year may range from late February in the lower Rio Grande Valley until the middle of May in the northwestern cotton limits of the State. As a matter of fact there are wide variations from the normal planting dates due to early or backward seasons in consequence of favorable or unfavorable temperatures, and the presence or absence of moisture.

Roughly speaking, a month to six weeks may elapse in a normal season after the last killing frost of spring before the soil reaches the best temperature for proper germination; examination of frost tables will show this to be a fact. The warming-up process in spring and, conversely, the chilling in autumn are more rapid in the interior of the State than near the coast.

For the best growth of the plant, sustained high temperatures are favorable, both night and day, with a summer mean of not less than 77° F. The older varieties of cotton required a growing season of not less than 200 days for best results. New short-season or precocious varieties, with much less vegetable growth have shortened the season considerably, especially in the northwestern and western sections of the State. Cotton now normally begins to mature in from 100 to 135 days after planting, with a maturing period ranging from possibly only two weeks to as much as two months.

The first killing frost in autumn does not hold as much dread as formerly due to the introduction of early varieties, tendency to earlier planting, and for other reasons. Excessive rain during time of harvest, thus delaying pick-

ing, beating out the open bolls, and staining the staple is, perhaps, a more detrimental factor than early frost danger.

Delayed planting due to late spring frosts, continued cold weather, excessive rain or drought is a greater deterrent to a full crop than ill-favored autumn conditions.

A poor "season" in the soil during the winter months is a marked factor for ill results, provided no balancing favorable weather follows during the season of (cotton) growth and maturity.

Wide variations in rainfall from month to month, especially during the growing season, are detrimental to yield. Excessive rain during the normal planting and cultivation season is rarely compensated for by sufficiently favorable weather during maturity and time of harvest to produce a normal crop.

Owing to the propagation and spread of the boll weevil since 1892, together with other insect pests to a lesser extent, new factors have arisen in recent years, materially complicating the weather and yield relationship. For instance in 1900, the second wettest year and the highest yield (219 pounds per acre) in this study (1899 to 1929, inclusive), the great cotton-producing counties of Williamson, Milam, Bell, Falls, McLennan, Limestone, Hill, Navarro, Ellis, Kaufman, Hunt, and Collin had not yet been invaded by the boll weevil. In 1919, the wettest year of record, and one of the five years of highest yield up to that time, weevil infestation had spread westward and northwestward to a line reaching from Wichita County to McCulloch, thence to Irion, thence to Valverde, or practically to its present limits, distinctly showing the reaction of weevil to rain, thus introducing a diametrically opposing factor, which was of minor consequence in 1900. Department of Agriculture data on reduction of cotton yield due to weevil damage amounted to 14 per cent in 1919, one of the three largest percentages of damage from like cause up to that time. Two years later, in 1921, weevil damage reached its peak in Texas, estimated at 33⅓ per cent, and cotton yield per acre dropped to its lowest ebb (98 pounds). The preceding winter had been unusually warm and fairly dry, followed by the wet months of April, June, and September, with alternating dry intervening months. The preceding winter weather was highly favorable for weevil during their dormant stage and large immergence in the spring. June, with the exception of 1899, was the wettest for that month in 31 years, seriously hindering proper cultivation.

January, 1922, February, March, and December, 1923, January, February, and December, 1924, and January, 1925, were all cold and well below their normals in temperature. It is interesting to note that they were followed by cotton seasons of constantly lessening weevil damage, reaching the lowest ebb in 1925 of only 2⅓ per cent or lowest since 1911. In 1925, the heat and drought of the following summer had a part in decreasing weevil activities; but this heat, at the same time, resulted disastrously for cotton, with the third lowest yield of record (113 pounds per acre). Following the warm winter of 1926–27, and mild, fairly moist summer, weevil emergence and damage again reached high marks, decreasing the yield by 20 per cent. While the cold December, 1927, and early January, 1928, somewhat lessened the weevil activities of the following summer, damage continued heavy (12 per cent), and was running high in 1929, with the second lowest yield per acre of record in prospect (108 pounds), due not only to abundance of insect pests, but to wide variations in monthly rain from the wettest of record in May to the general droughty conditions and the second driest August of the period considered.

An unfortunate and interesting tendency is known in connection with cotton insect and fungous pests, which comes under the general term, adaptation—to fit into changing environments. Overspecialization of a pest will ultimately make its destruction inevitable; the least adaptable will fall by the wayside while the more versatile pest persists.

To a certain extent the hosts, such as cotton, may be sufficiently adaptable to meet in part the onslaught of pests and grow stronger in specific adaptations. This fact is no doubt recognized in certain varieties, but is somewhat foreign to a study of weather and cotton yield, just as are the natural deterioration and erosion of the soil under constant cotton cropping, with resultant inevitable decline in yield. It is interesting to note in this connection, however, that a study of cotton yield in Texas during the last three decades shows the acre-yield for the whole period to have averaged 150 pounds, while the first decade shows an average of 169, the second decade of exactly 150, and the third or last decade shows only 131 pounds—a decline of 38 pounds per acre or 22½ per cent from the first decade, 1899 to 1908, inclusive.

It is quite obvious from this study that purely weather factors alone, which might have produced a fair or reasonably good crop in the early years, under happier conditions of better soil and fewer battling pests, may well produce an extremely short crop due to new factors or hazards at the present time.

High percentage of sunshine with resulting abundant warmth and low humidity are factors which tend to hold down weevil ravages and even destroy the weevil. Despite this very type of weather in the later summer weeks of this year, however, it is said that the overlapping of broods enabled the insects to be especially destructive in many places in Texas, more especially the south half. Perhaps this is an example of weevil adaptability.

Sunshine is usually in inverse ratio to rainfall or directly in proportion to the heat of summer.

TABLE 1.—*Weather and cotton yield in Texas*

Year	Mean temperature: Departure from normal				Killing frosts		Mean precipitation: Departure from normal				Boll Weevil Infestation line	Per cent of damage	Cotton yield, pounds	Departure from normal	
	Winter	Spring	Summer	Autumn	Spring	Autumn	Winter	Spring	Summer	Autumn				Decade	31 years
1899	−	+	+	+	L	E	−	−	+	+	S	----	174	+5	+24
1900	N	−	−	+	E	L	N	+	+	+	S	----	219	+50	+69
1901	+	−	+	+	E	L	−	−	−	−	A	----	156	−13	+6
1902	−	+	+	+	E	L	−	−	+	+	S	----	144	−25	−6
1903	−	−	−	−	L	L	+	−	+	−	A	----	139	−30	−11
1904	N	+	−	+	N	N	−	−	+	N	A	----	179	+10	+29
1905	−	N	N	+	N	E	N	+	+	+	A	----	157	−12	+7
1906	−	−	−	−	N	N	N	−	+	N	A	----	214	+45	+64
1907	+	−	N	N	E	L	−	+	−	+	S	----	125	−44	−25
1908	+	+	−	−	E	N	−	+	+	N	S	----	187	+18	+37
1909	+	N	+	+	L	N	−	−	−	−	S	12	119	−31	−31
1910	−	N	+	+	N	N	−	−	−	−	S	7	145	−5	−5
1911	+	+	+	N	E	E	−	N	−	−	R	1	180	+30	+30
1912	−	−	+	N	N	L	+	−	−	−	A	3	197	+47	+47
1913	−	−	N	−	N	E	N	−	−	+	R	7	144	−6	−6
1914	N	−	+	+	L	N	N	+	+	+	A	8	177	+27	+27
1915	−	−	−	+	L	L	N	+	N	−	A	16	140	−10	−10
1916	+	+	+	N	N	N	−	−	+	−	S	18½	150	0	0
1917	+	−	+	−	L	E	−	−	−	−	S	7	135	−15	−15
1918	−	+	+	−	E	L	−	−	−	+	R	4½	115	−35	−35
1919	−	−	−	N	E	N	+	+	+	+	S	14	136	−3	−14
1920	+	N	−	+	L	L	+	−	+	+	A	20	167	+28	+17
1921	+	+	N	+	L	L	−	N	−	−	S	33⅓	98	−41	−52
1922	+	+	+	+	N	L	N	+	−	−	----	16	126	−13	−24
1923	+	N	+	−	N	L	+	+	−	+	----	10	143	+6	−7
1924	−	−	+	+	L	L	+	+	−	−	----	7½	136	−3	−14
1925	−	+	+	−	E	E	−	−	−	+	----	2⅓	113	−26	−37
1926	−	−	N	+	N	L	−	+	N	N	----	11	147	+8	−3
1927	+	+	N	+	L	E	+	−	+	N	----	20	129	−10	−21
1928	N	N	+	−	N	N	+	−	N	N	----	12	139	0	−11
1929	−	+	+	−	X	X	+	+	−	+	----	----	108	−31	−42

(+) Above normal. (−) Below normal. (N) Normal. (E) Early. (L) Late. (A) Advanced. (R) Retreated. (S) Stationary.

Mean yield: 1899 to 1908, inclusive, 169 pounds; 1909 to 1918, 150 pounds; 1919 to 1929, inclusive, 131 pounds. Mean of 31 years, 150 pounds. No attempt made in above table to state amount of departures in exact amounts for temperature and precipitation.

CONCLUSIONS

Good winter and early spring subsoil moisture indicates a good cotton season; but unfavorable condition during growing season, such as violent monthly rainfall change from wet to dry, continuous heavy to excessive rains, with resulting poor cultivation and heavy weevil infestation, may easily offset the early advantage. A cold winter tends to destroy the hibernating insects and cut down the spring emergence; this favorable cotton factor, however, may be offset by late planting and a moist cool growing season, favoring the rapid multiplication of pests at a time when they will do the greatest harm to the delayed crop. On the contrary the disadvantages of a dry, abnormally warm winter or a late cold or extremely wet spring may be largely compensated for by later exceptionally favorable weather conditions.

Other things being equal, the ideal year for cotton would be one in which there was good soil-moisture storage during the preceding winter, which should be sufficiently cold to destroy the hibernating pests; followed by an early spring of moderate rainfall, promoting planting and cultivation of crop; a moderately dry, hot summer, with abundant sunshine, but not really droughty and not subject to sharp reversals in rainfall or temperature, thus favoring care and growth of crop and holding down weevil (this condition would favor certain other insects, however, of less serious nature). Finally, a fairly dry, bright autumn and late frost, to remove all of the cotton from the fields without deterioration or loss.

The vast area of Texas greatly complicates the study of weather and cotton yields. Within the State's borders, we have the semitropical climate of the lower Rio Grande Valley and the rigorous Temperature Zone climate of the Panhandle; the 50-inch annual rainfall of the lower Neches and Sabine Rivers in the southeast to the 10-inch rainfall of the extreme west; the long, flat reaches of the Coastal Plain to the high cap-rocked Llano Estacado and the rugged Trans-Pecos region.

Through the wide reaches of the State from the marine climate of the coast to the continental climate of the interior, there seems to be a persistent tendency toward zonal rainfall, i. e., for heavy precipitation to occur along the coast or paralleling it, even for hundreds of miles inland, materially affecting the average moisture over the State, and yet remaining more or less localized. While this fact is known, in a general review like this present study it is impracticable to enter into a discussion of these more specialized conditions, which often complicates the whole study, and deserves and should receive a careful analysis as to causes, locations, and frequency.

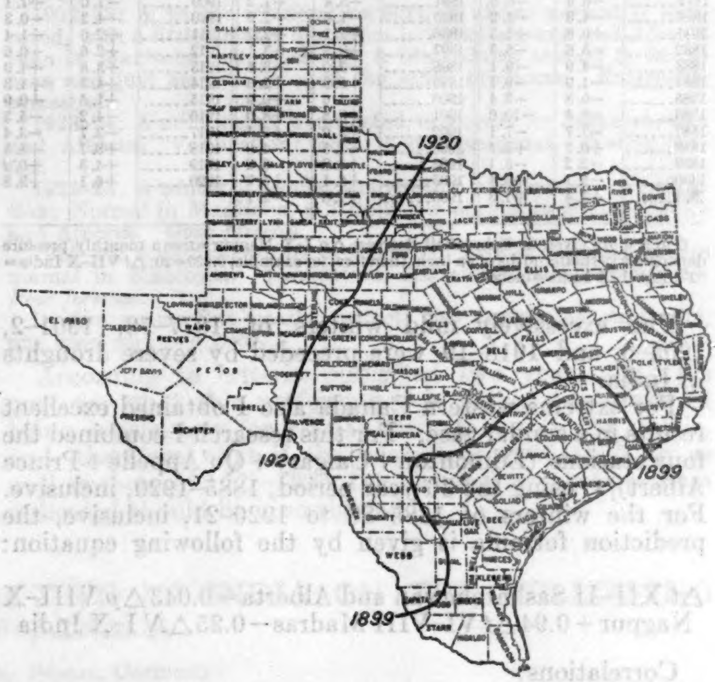

FIGURE 1.—Spread of Mexican cotton-boll weevil 1899-1920. Not much advance since 1920

For further study on weather and agriculture in general see Department of Agriculture Yearbook, 1924, pages 457 to 558, inclusive, by A. J. Henry, J. B. Kincer, H. C. Frankenfield, and W. R. Gregg, of the Weather Bureau, B. B. Smith, Bureau of Agricultural Economics, and E. N. Munns, Forest Service; Climatic Factors in the Agriculture of Louisiana and Southern Mississippi by W. F. McDonald, Weather Bureau, New Orleans.

RELATIONS BETWEEN SUMMERS IN INDIA AND WINTERS IN CANADA[1]

By FRED GROISSMAYR

(Passau, Germany, September, 1929)

The weather elements of Argentina, Egypt, and especially East India are of enormous influence upon the following Canadian winters, nine months to three months later, as the correlation table distinctly shows:

Δt XII–II Winnipeg, Manitoba, 1877–1878 to 1920–1921

Correlations with preceding elements:

Argentina	Egypt	India
Goya: Δt I-VII: +0.55 ΔN IV: +0.51	Nile VII-X at Assuan −0.50	Δp I-X Nagpur +0.74 Δt VII-X India +0.73 ΔN I-X India −0.56

t = temperature, p = pressure, N = precipitation, I–XII = months, Δt VII–X India = (Cochin + Madras)/2; ΔN I–X India = (Jaipur + Nagpur + Allahabad + Masulipatam + Waltair)/5. Uniting Goya January–July temperatures and the three Indian weather elements, I have obtained the following:

Winter temperature forecasting formula for Winnipeg:
Δt XII–II Winnipeg = 0.13 Δp I–X Nagpur + 2.6 Δt VII–X India − 0.13 ΔN I–X India + 0.85 Δt I–VII Goya.

These four elements give a total correlation of, $r = 0.81$ with Δt XII–II Winnipeg; the computed values (de-

[1] Much of the preliminary work on which this note is based is described in a previous paper published in the May, 1929, issue of *Meteorologische Zeitschrift* under the title "Der Einfluss der Wetterfaktoren Indiens auf den Folgewinter Kanadas." See abstract and excerpts on following pages.—*Editor.*

partures) in case of this formula agree very well with the actual ones, as the following table shows:

[C=computed, a=actual, 1877=winter of 1877-1878]

	C	a		C	a		C	a
1877	+10.8	+17.9	1892	−9.9	−7.7	1907	+3.8	+9.1
1878	−1.4	−2.9	1893	−3.9	−4.6	1908	−0.1	+1.5
1879	−6.6	−6.6	1894	−5.4	+1.2	1909	−1.0	+1.1
1880	−4.0	−4.2	1895	−1.0	+2.2	1910	−4.2	−0.3
1881	+0.8	+3.3	1896	+2.1	+2.2	1911	+2.6	+1.4
1882	−5.6	−8.3	1897	+0.8	+3.1	1912	+2.6	+0.6
1883	−4.9	−9.1	1898	−2.0	−3.6	1913	+3.8	+4.9
1884	−1.9	−9.1	1899	+5.9	+2.6	1914	+4.7	+4.3
1885	−0.8	−3.4	1900	+4.6	+0.9	1915	+1.6	+0.9
1886	−6.4	−10.0	1901	+3.8	+8.0	1916	−4.2	−5.3
1887	−7.7	−7.1	1902	+5.0	+2.1	1917	−3.7	−3.4
1888	+0.7	+3.4	1903	−1.5	−4.0	1918	+8.7	+8.3
1889	−2.2	−5.1	1904	+1.8	−0.2	1919	+4.3	+0.2
1890	−5.1	+3.4	1905	+6.1	+5.7	1920	+6.1	+8.8
1891	+3.4	+1.3	1906	+1.0	−2.7			

C and a are given in Fahrenheit degrees; Δp I-X Nagpur=mean monthly pressure departures in thousandths of an inch, therefore, for example, 0.020=20; Δt VII-X India=°F.; ΔN I-X India=inches.

The excessively mild winters of 1877-78, 1901-2, 1905-6, and 1918-19 were preceded by severe droughts in India.

For extreme western Canada also I obtained excellent results in a similar case. For this research I combined the four stations (Edmonton+Calgary+Qu'Appelle+Prince Albert)/4, using the 36-year period, 1885-1920, inclusive. For the winters of 1885-86 to 1920-21, inclusive, the prediction formula is given by the following equation:

$$\Delta t \text{ XII–II Saskatchewan and Alberta} = 0.043\,\Delta p \text{ VIII–X Nagpur} + 0.94\,\Delta t \text{ VI–VIII Madras} - 0.25\,\Delta N \text{ I–X India}$$

Correlations:

$$\left.\begin{array}{ll} \Delta p \text{ VIII–X Nagpur} & +0.62 \\ \Delta t \text{ VI–VIII Madras} & +0.62 \\ \Delta N \text{ I–X India} & +0.72 \end{array}\right\} \text{Total correlation} = 0.75$$

Agreements of C and a (years in which $C \geqq \pm 3°$ F.).

	C	a		C	a
1886	−5.8	−10.6	1907	+3.1	+8.2
1889	−3.4	−9.8	1910	−4.0	−3.9
1892	−6.8	−4.7	1911	+3.1	+1.9
1893	−4.7	−4.0	1913	+3.6	+4.0
1894	−4.1	−2.0	1916	−5.4	−5.9
1896	+4.7	+1.1	1917	−7.3	−6.1
1899	+5.8	+0.8	1918	+5.9	+6.9
1903	−3.8	−1.8	1920	+4.3	+5.7
1905	+3.7	+7.0			

Here we find agreement in respect to plus or minus of a and C in all cases for which $C \geqq \pm 3°$ F.; very close is the influence of Indian rainfall in all the years in which the *mean* departure of rainfall sum (January to October) was $\geqq \pm 4$ inches (per *one* of these five Indian stations); the following winter in Saskatchewan and Alberta had the contrary character.

	1886	1887	1888	1889	1892	1893	1894	1896	1897	1898	1899	1901
N	+7	+4	−4	+4	+15	+8	+11	−11	−6	+5	−12	−4
t	−10.6	−6.1	+6.8	−9.8	−4.7	−4.0	−2.0	+1.1	+2.2	−2.1	+0.8	+6.7

	1902	1903	1905	1907	1910	1911	1913	1915	1916	1917	1918	1920
N	−4	−4	+5	−7	−8	+5	−7	+6	+11	14	−13	−6
t	+1.4	−1.8	+7.0	+8.2	−3.9	+1.9	+4.0	−2.7	−5.9	−6.1	+6.9	+5.7

Accidental? Never! The diagram of winter temperature departures (fig. 1) shows the close parallelism of the actual and the computed data.

DISCUSSION

(Clark University, Worcester, Mass., November 24, 1929)

The extraordinarily high correlation found by Mr. Groissmayr between pressures, temperatures, and rainfall of certain tropical regions and the later winter temperatures in the interior of Canada challenges North American meteorologists (1) to test Mr. Groissmayr's claims by applying his formulas to the years after the period he used in making it, (2) to study the physical basis for such a correlation, and (3) to explore other possibilties not only for predicting winter mean temperatures but also for other seasons and for all parts of the continent.[1]

As a beginning, I submit the following computations, according to Mr. Groissmayr's formulas, for the six winters, 1920-1926 (the first one being the last in the

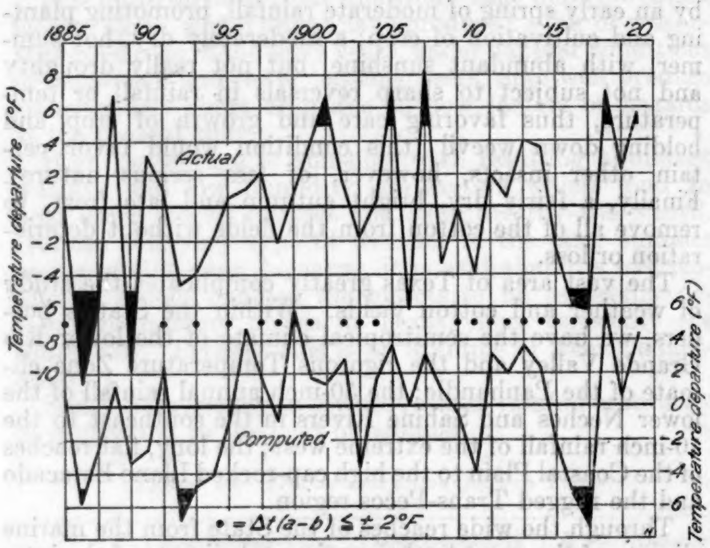

FIGURE 1.—Graph of actual and computed temperature departures in Canada, 1885-1920

long period of years used by him), and what the formula seems to indicate for the winter of 1929-30.

Winter mean temperature departures °F

	Winnipeg			Saskatchewan and Alberta		
	Computed		Actual	Computed		Actual
	Official	Clayton		Official	Clayton	
1920-21	+7.0	+7.2	+9.2	+4.1	+4.2	+6.2
1921-22	−1.8	−0.8	+4.3	+1.4	+1.5	−0.1
1922-23	+1.0	+2.0	+1.1	+2.8	+2.9	−0.5
1923-24	+1.2	+2.9	+8.1	+3.7	+3.8	+6.8
1924-25	−2.1	−0.5	−0.1	+0.6	+0.7	−3.0
1925-26	[a] +0.1	[a] +0.9	+9.0	−0.5	−0.4	+12.2
1929-30	[b] +0.6	[b] +1.4	....	[b] +1.6	[b] +1.4	....

[a] Goya term omitted. [b] October data omitted.

For 1920-21, neither the computed nor the actual departures of winter temperature correspond exactly to Mr. Groissmayr's figures, though they are nearly the same. In the first column, "Official," I used simply the departures as published in official reports, in the

[1] *Cf.* Groissmayr's tropical indicators for autumn temperatures in the eastern United States, Monthly Weather Review, July, 1926, 54: 290; January, 1929, 57; 20-21.

second, "Clayton," I used Clayton's World Weather Records, as, apparently, Mr. Groissmayr had, and obtained, my departures from the Clayton normals, except for 1929 Goya temperatures, when only the departures were available in the Argentine "Resumen Mensual."

Of the 44 winters used by Groissmayr for Winnipeg, the calculated and actual departures were the same in 37, or 84 per cent. The additional five winters show similar correspondence. Droughts in India preceded five of the six warm winters in Groissmayr's series, but only one of the two warm winters in the new series.

In view of the shorter period of years, 36, for Saskatchewan and Alberta, Mr. Groissmayr gives only the larger indications, and shows that for computed departures $\geqq \pm 3°$ F. there is *invariable* agreement of the subsequent winter temperature as to sign. In the new series, the one strong indication of a warm winter was likewise verified.

In the 24 years when India was unusually wet or dry, Groissmayr shows that Saskatchewan and Alberta winters have been, *without exception*, below or above normal in temperature. The year 1922 (January to October) averaged 6 inches below normal and 1925 averaged 6 inches above normal; the following winter temperatures were, respectively, below normal and above normal, breaking the rule. Two-thirds of the excess of rainfall in 1925, however, occurred at but one of the five stations and in a single month.

If the forecasting formula had been applied for the five winters 1921–1926 and the results published in advance of each winter, the forecasts and verifications would have run about as follows:

1921–22: A winter of normal temperature is indicated, possibly slightly below normal in Manitoba and above normal in Saskatchewan and Alberta. Verification: A moderate degree above normal in Manitoba and normal in the other prairie Provinces. *Reasonably successful.*

1922–23: A winter temperature slightly above normal is indicated, with a little greater departure in Saskatchewan and Alberta than in Manitoba. Verification: A little above normal in Manitoba and just under normal in the other Provinces. *Reasonably successful.*

1923–24: A mild winter is indicated, especially for Saskatchewan and Alberta. Verification: Very mild throughout. *Nearly perfect.*

1924–25: A winter of normal temperature is indicated. Verification: Normal in Manitoba, a little below normal in Saskatchewan and Alberta. *Good forecast.*

1925–26: A normal winter is indicated, possibly slightly above normal in Manitoba. Verification: Extremely mild throughout. *Poor forecast.*

In five years: One nearly perfect, two reasonably successful, one good and one poor.

According to criteria published two years ago [2] we may say that this performance is within the limits of being satisfactory for official presentation to the public, and, therefore, that if the winters of 1926–1930 do as well as those of 1921–1926, the physical connections here indicated should be investigated.

THE INFLUENCE OF THE WEATHER FACTORS IN INDIA ON THE FOLLOWING WINTER IN CANADA

By FRED GROISSMAYR, Passau, Germany

(Abstract and excerpts by C. F. Brooks; translation by W. W. Reed, of "Der Einfluss der Wetterfaktoren Indiens auf der Folgewinter Kanadas." *Met. Zeitschr.*, May, 1929, 46:176)

Following the lead of E. W. Bliss,[1] who gives four somewhat useful correlation coefficients indicating winter temperatures for central North America from previous conditions about the Indian Ocean, the author sought higher correlations by adding more tropical elements and localizing the North American end. The factors used by Bliss were pressure at Mauritius, temperature at Batavia, the Nile flood, and Indian rainfall. Since Schostakowitsch had found that over the Indian-Australian region temperature and pressure varied together while precipitation went opposite, the author added Indian temperature and pressure and Batavia and Egypt pressures, and also weather conditions of Argentina, which has long association with other Indian monsoon indicators.

"For the whole area investigated [in central North America] the pressure and temperature of India prove more influential than the monsoon rains of northwest India. With the exception of Montreal, the pressure over central India is more closely connected with the winter temperature of the region under consideration than is the summer of south India. Especially close relations resulted for the winter in Manitoba; also the autumn temperatures of Bombay, and that of Labore plus Allahabad show uncommonly close correlation with the character of the cold season at Lake Winnipeg."

1876–1920: Δt IX–XI Allahabad plus Lahore with Δt XII–II Winnipeg: $r=0.62$.

1878–1920: Δt IX–XI Bombay with Δt XII–II Winnipeg: $r=0.66$.

After an especially cool autumn —2° F. or more below normal—in northwest India there always followed a severe winter at Winnipeg, and after a warm autumn—2° above—a relatively mild winter.

	1876	1877	1879	1884	1896	1907	1917	1920
Δt IX-XI Allahabad and Lahore	−2.0	+2.5	−2.0	−2.6	+2.7	+2.5	−2.7	+2.6
Δt XII-II Winnipeg	−0.8	+17.9	−6.0	−9.1	+2.2	+9.1	−3.4	+8.8

Such decided relations led to further study of tropical factors with respect to Winnipeg's winters and to the discovery of the additional very notable correlation coefficients: With Nile flood, at Assuan, 1873–1922, $r=-0.52 \pm 0.07$; with Batavia October pressure departure, 1873–1922, $r=+0.54 \pm 0.07$; with Batavia October and November temperature departure, $r=+0.60 \pm 0.06$, and with Goya, Argentina, temperature departure April to July, $r=+0.52 \pm 0.07$. Pressure over central India proved most closely correlated with the subsequent winter at Winnipeg, especially when advantage was taken of the pronounced tendency of weather in the tropics to maintain an existing departure.

The mean monthly pressure departure at Nagpur from January to October is correlated with the departure of the winter temperature of Canada and of the north central part of the United States, the coefficient for Winnipeg being, $r=+0.77 \pm 0.04$, "the highest correlation ever

[1] E. W. Bliss, World Weather III, Memoirs, Quar. Jour. Roy. Metl. Soc., vol. II, No. 17, — pp.

[2] Charles F. Brooks, Performance in Long-range Forecasting. MONTHLY WEATHER REVIEW, September, 1927, 55:390-395, including bibliography.

obtained between different weather elements of widely separated stations and at disconnected times. The correlation here exceeds nineteen times the amount of the probable error. Other Indian stations show high positive correlations, for example, Bangalore pressure, January to October with Winnipeg winter temperature, $r = +0.43$. In all cases in which the mean monthly pressure departure at Nagpur for January–October equaled or exceeded 20 ($\frac{1}{1000}$ inch) the winter temperature at Winnipeg had the same sign of departure." The highest India pressure, of 1877, was followed by the mildest winter at Winnipeg. Pressure maximum in India is associated with winter temperature maxima later over an immense part of Canada and the United States.

"The summer and autumn temperature of the western and eastern coasts and likewise of the interior of India show high correlation of like sign to the winter of North America, from the mouth of the St. Lawrence to Montana and Saskatchewan. Here also Winnipeg holds the record.

"The rainfall of India likewise proves of special significance relative to the region around Lake Winnipeg." Though most of India's rainfall comes in June to September, it appeared advantageous to include all the months, January to October. This element shows negative correlation.

By the method of partial correlations these three elements of India were combined into a regression equation, which gave a coefficient of $r = +0.81$ (1875–1920):

$$\Delta t \text{ XII–II Winnipeg} = +0.21\Delta p \text{ I–X Nagpur} + 1.00\Delta t \text{ VI–VII Madras} - 0.10\Delta N \text{ I–X (Jaipur + Lahore)/2}$$

p stands for pressure (thousandths inch), t for temperature (°F.), and N for precipitation (inches). The mean difference between calculated and observed temperature at Winnipeg is but 2.9° F., which is but 52 per cent of the mean winter temperature anomaly of 5.6° F. All cases of calculated departures of 5° or more (15 of the 46 years) have winters of the same sign; and all warm or cold winters 5° or more from normal agree in sign with the calculated departure. In very many cases there is the possibility of a nearly certain forecast; of the 28 cases of calculated departures of 3° or more, 26 winters have the same sign. Calculated and observed departures of any size agree as to sign for the whole 46-year period in 80.4 per cent of the cases.

"In addition to the weather elements of India the winter of Manitoba is effectively influenced by the October air pressure and the October-November temperature at Batavia; both correlations are positive,"

$r = +0.54$ and $+0.60$, resp., 1873–1922

The Nile flood shows nearly the same negative correlation with the succeeding winter at Winnipeg as for that of central Europe.

Central Argentine temperature, at Goya, from April to June, is correlated with the Winnipeg winter, $r = +0.52$ (1877–1920). In all cases where Goya temperature was 1.5° C. or more above or below normal (8 years out of 44) the winter in latitude 50° N. and in longitude 100–105° W. had the same sign.

Egyptian pressure in summer, July at Cairo, has a correlation with the following winter at Winnipeg, $r = 0.44$ (1873–1922).

Cold winters in subarctic continental North America are as a rule snowy, and the mild winters deficient in precipitation; thus it is not particularly surprising to find Nagpur pressure, January-October, correlated with Bismarck winter precipitation, $r = -0.50 + 0.07$. Similar values were found for the other stations.

The winters of central Europe are indicated by the same factors as are those of Canada. These are the weather elements of India and of the Sunda Sea in summer and autumn of the Southern Hemisphere; also, here we have again the interaction of Argentine weather in the autumn of the Southern Hemisphere with the monsoon intensity over the northern part of the Indian Ocean. The weather elements of Egypt are functions of the southwest monsoon, not of the Atlantic Ocean. Stronger southwest monsoon in India brings copious rains, with low pressure and relatively cooler weather in India itself. For cold winters the scheme reads:

Canada	*Central Europe*
$-p$ I–X India.	$-p$ I–X India.
$-t$ VI–XI India.	$-t$ VI–XI India.
$+N$ I–X India.	$+N$ VIII–XI India.
$-t$ IV–VII Argentina.	$-t$ IV–VII Argentina.
$-N$ I–VII Argentina.	$-N$ I–VII Argentina.
$+p$ IV–VI Argentina.	$+p$ IV–VI Argentina.
$-p$ VI–VIII Egypt.	$-p$ III–VIII Egypt.
+Nile VII–X Egypt.	+Nile VII–X Egypt.
$-p$ X Java.	$-p$ X Java.
$-t$ X–XI Java.	$-t$ X–XI Java.

THE DAILY MARCH OF TEMPERATURE AND HUMIDITY [1]

By V. E. SHELFORD

[V. E. Shelford, Vivarium Building, Wright and Healy Streets, Champaign, Ill.]

A study of development of the various stages of the codling moth carried out a few years ago (Shelford, 1927), indicated that the evaluation of rates of development must be based upon a combination of temperature and moisture. These two factors vary roughly reciprocally and are quite inseparable for that reason.

In this study experiments were carried out in great detail on the pupa. For this stage a chart was made showing the rate of development at each combination of temperature and humidity under which the pupa would live and develop. The chart is shown in Figure 1. Rates or velocities are given in developmental units per hour, the developmental unit being the difference in amount of development between a given degree of medial temperature and the amount 1° higher. The total is measured in terms of the total number of hours to complete the stage at several medial temperatures. Lines connect combinations of temperature and moisture giving the same rate. The figures at the right of the curve show the developmental units per hour characteristic of each line. Under average conditions the total (°F. and hour) developmental units required to complete the pupal stage is 6,480. One hour at 75 per cent humidity and 54° F. gives 5 units while one hour at 80 per cent humidity and 89° F. gives 37 units. In preparing this chart, variable temperature experiments were introduced. In these chambers the temperature rose during the forenoon when the sun was shining through the glass roof of the room or when large incandescent lamps were turned on during cloudy days. It fell off in the afternoon and was

[1] Contribution from the Zoological Laboratory of the University of Illinois, No. 355.

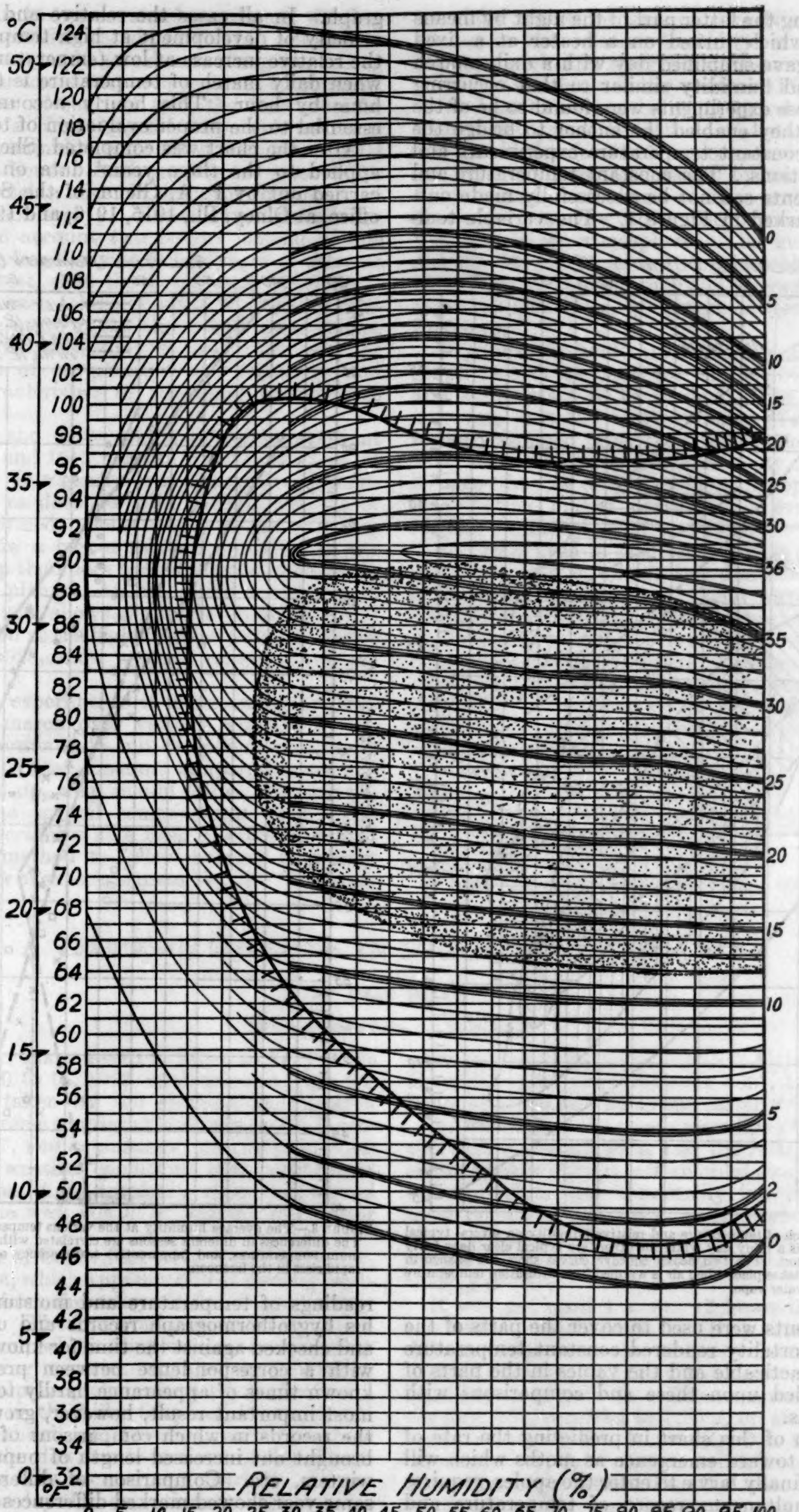

FIGURE 1.—The chart made for the codling moth pupa, in which the curved lines connect temperature and humidity combination in which the rate of development is the same. The figures at the right are the velocities, in developmental units per hour characteristic of the lines opposite. The heavy line indicates the limits of successful constant temperature experiments. Medial temperatures are those withinwhich the laws of the equilateral hyperbola hold good

held constant during the latter part of the night by means of a thermostat which turned on a heater at a fixed minimum. This gave simplified day with a daily march of temperature and humidity similar to that occurring out of doors. These experiments were found to be of the greatest value as they enabled the author to bridge the gap between the constant temperature experiments and the weather conditions. The constant temperature and humidity experiments can not be successfully made outside the limits marked in Figure 1. The variable tem-

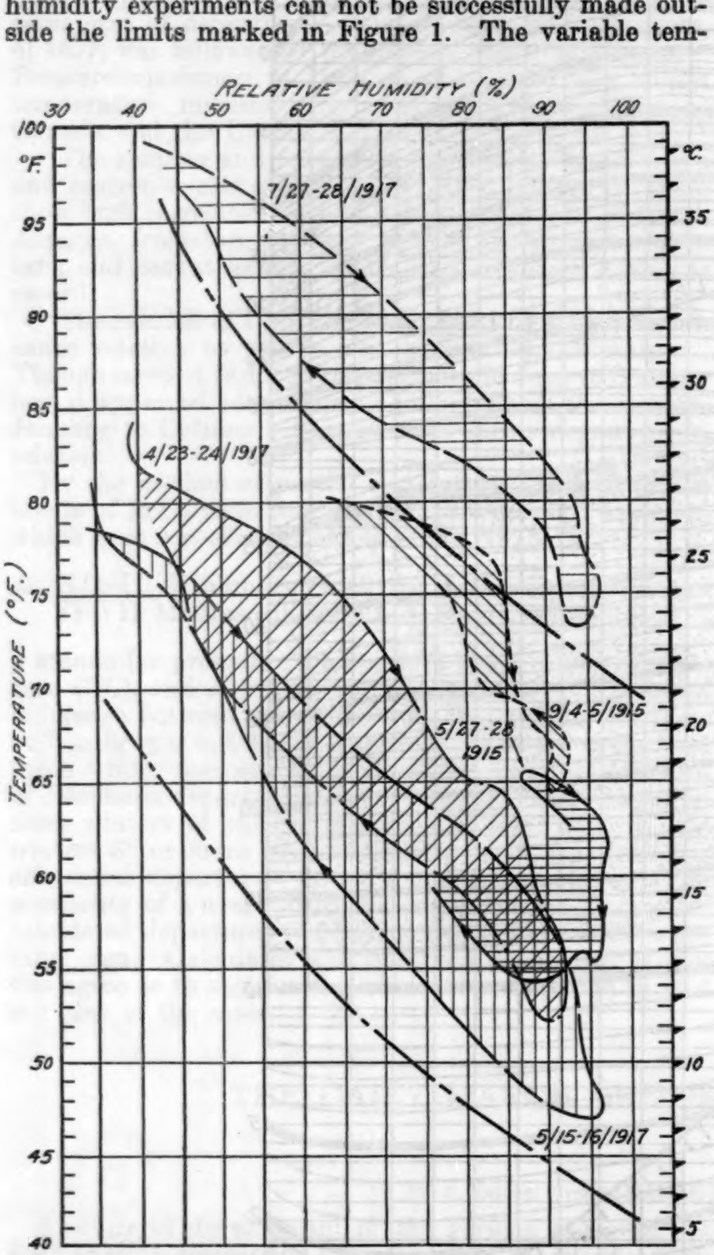

FIGURE 2.—The daily march of temperature and relative humidity on several typical days. May 27-28, 1915, is a rainy day while the others are typical clear days fairly characteristic of the season. The two heavy concave curves show the change in relative humidity which takes place when air is warmed from saturation temperature without the addition of water vapor

perature experiments were used to cover the parts of the chart in which mortality rendered constant temperature experiments impracticable and the values in the parts of the chart depended upon these and comparisons with outdoor conditions.

The application of this chart in predicting the rate of progress of pupæ toward emergence as moths which will provide eggs and finally larvæ to enter the apples, requires a continuous simultaneous record of temperature and humidity such as may be made with a Friez hygrothermograph. In all cases the relative and actual decrease in velocity of development at high temperatures as well as the relative increase at low temperatures is accounted for when daily march of temperature is taken into account hour by hour. This hourly accounting is absolutely essential to the proper evaluation of temperature results.

After the chart was completed (Shelford, 1927), it was applied to the three years' data on the codling moth carried out by P. A. Glenn, of the State entomologist's office, at Olney, Ill., 1915, 1916, and 1917. Thousands of

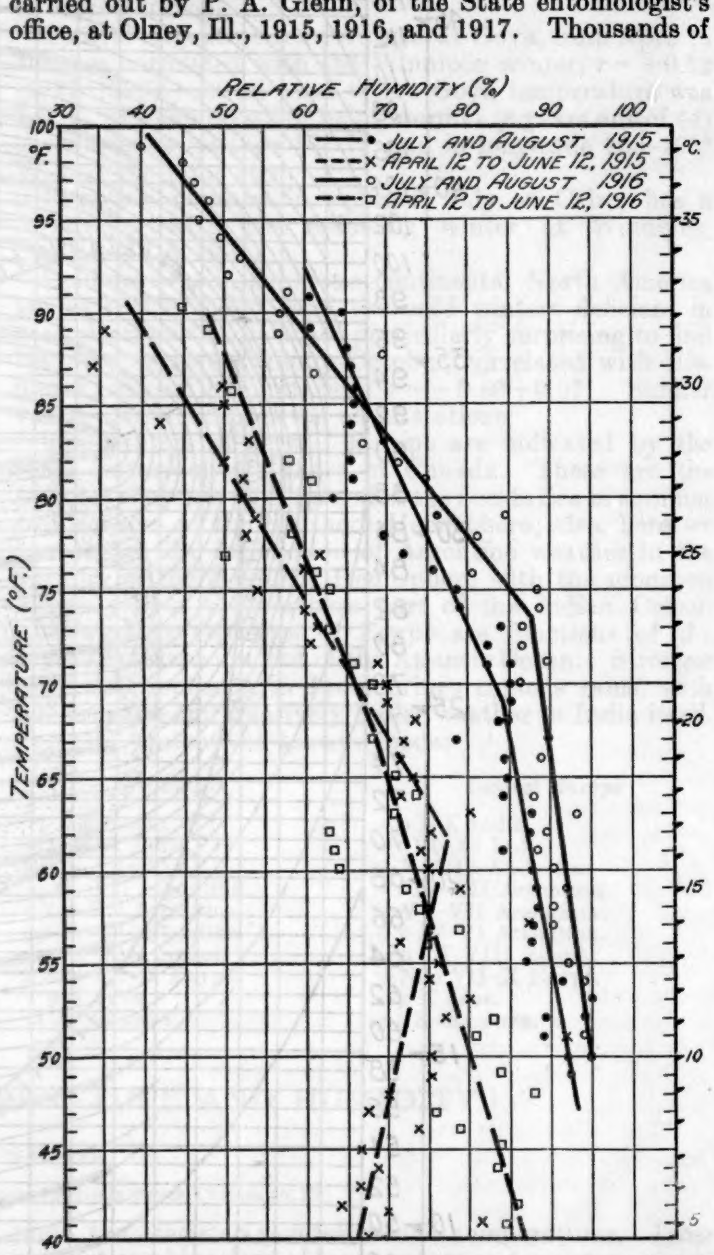

FIGURE 3.—The average humidity at the various temperatures for the periods noted. The differences in different seasons are correlated with rainfall, maximum and minimum temperatures, and (apparently) transparency of the atmosphere which gave rapid rises in the forenoon.

readings of temperature and moisture were taken from his hygrothermograph records and used with the chart and checked against the time for known life history stages with a correspondence between prediction and actual known times of appearance hardly to be expected. The most important result, however, grew out of a study of the records in which comparisons of the different years brought out increased length of pupal life following dry winters, etc. Comparison of different seasons in the same year showed marked differences with rising and falling temperature. While the differences due to humidity

amount to less than 15 per cent under ordinary weather conditions, differences due to winter rainfall apparently amount to 10 per cent, and those due to rising and falling temperatures appear to amount to as much as 18 per cent. To determine either of the last two, the first must be eliminated. Glenn's Friez hygrothermograph readings of temperature and humidity were taken from the original sheets on the even hours. Such records are essential to the application of such a chart in practical prediction of the time of application sprays. The chart has the advantage of taking into account two factors instead of one factor and of being less likely to fail in years of extreme abundance of the pest, than the simple sum of temperature which can not even take account of the various relative effect of temperature at the higher and lower values.

In connection with this study several other uses for continuous records of temperature and humidity and some general characteristics of the daily march were made out.

Figure 2 shows the daily march of temperature at Olney, Ill. in 1915 and 1917. From 2 p. m. to 12 m. of the following day. In a general way the relative humidity changes much as does air with a fixed amount of humidity when warmed. Some days, as for example, April 23, 1924, show a higher relative humidity as the temperature goes up than does heated air due to evaporation from soil and plants. An occasional summer day, as e. g., July 27, 1928, shows a relative humidity lower than is to be expected at the higher temperatures. Rainy days as May 27, 1928, show a small range of relative humidity.

In preparing for experiments it is necessary to have the average daily march over various portions of the growing season determined to suit the plants or animals being considered. Where constant temperature experiments are to be set up, they should fall on the average daily march at the several temperatures used. The use of several temperatures at a fixed relative humidity is not a desirable method to follow because it greatly increases the number of experiments to be run. The average daily march for various periods was worked out by averaging the relative humidity at each temperature taking a period in the growing season which is of significance for the form being studied (Fig. 3.) This April 12 to June 12 covers the usual period of maximum numbers of codling moths in the pupal stage. The low average humidities for 1915 as compared with 1916, at the low temperatures, are shown by an inspection of the hygrothermograph sheets to be correlated with a sharp rise in temperature during the morning hours, probably due to a clear atmosphere. The months of July and August in 1916 showed considerable difference from 1915 both in temperature and average humidity at the same temperatures. Nineteen-sixteen was a year of extremes.

Experiments should have several years of hygrothermograph records at hand for the locality in which plants and animals are to be studied. The writer has found, however, that the United States Weather Bureau has recently stopped using these instruments quite generally. They should be in service in as many stations as possible because the use of the reciprocally operating factors in combination makes possible the evaluation of other factors. (Shelford 1927 and 1929.)

The scale used in diagrams such as are presented here is the one used in all the two dimension diagrams made in the author's laboratory. They have been based upon 5° C. equals (in actual scale distance) 50 millimeters rain or 20 per cent relative humidity. Accordingly, 9° F. equals (actual scale distance) 2 inches precipitation and 20 per cent humidity. This makes possible the plotting of weather data from either Fahrenheit or centigrade. Diagrams on different scales can not be readily compared without redrawing.

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A TROPICAL CYCLONE IN SOUTHERN CALIFORNIA [1]

By DEAN BLAKE

[Weather Bureau Office, San Diego, Calif.]

Receipt of weather maps issued at Mexico City for the period September 10 to 18, 1929, enables us to trace the approximate path taken by the storm that appeared unheralded over extreme southern California on the morning of September 17, and to substantiate the conviction that the abnormal weather conditions that occurred at that time were the result of a tropical cyclone that moved northward along the west coasts of Mexico and Lower California.

On the afternoon of September 16 a remarkably dry, desiccating hot wave, which apparently was moving westward, was reported from the valleys in San Diego County back from the coast. The first word came from El Cajon, about 14 miles inland, where temperatures considerably over 100° were being experienced. As the afternoon advanced, alarmed citizens, who associated the heat with brush fires burning in the hills, telephoned from points progressively nearer the city, and near 4 p. m. temperature contrasts between the downtown sections of San Diego and the surrounding hills became very marked. It was about this time of the day that exceptionally high maxima were registered in the county, El Cajon reporting 111°, Escondido 107°, and Ramona 102°, these temperatures being accompanied by strong easterly winds.

At the station the winds were light to gentle and from the west and northwest, and the relative humidity only slightly below normal. Two miles away, however, strong easterly winds and abnormally low relative humidities were reported, and many people who experienced the change between the two currents commented upon its suddenness and abruptness, the line of demarcation being sharply defined.

It was not until 4 a. m., 12 hours later, that the hot wave finally reached the San Diego station, but when it did the temperature rose suddenly from 70° to 94° in less than 30 minutes, and there was a decrease in the relative humidity to 16 per cent. The maximum temperature for the day, 95°, occurred at 7:30 a. m. after which hour the temperature slowly decreased, due to the increasing cloudiness and later to the rainfall. Although at sundown the night before the sky was cloudless and the relative humidity was 72 per cent, at 8:55 a. m. a sprinkling rain began with a relative humidity of only 38 per

[1] Cf. Hurd, W. E., This REVIEW, vol. 57: 397-8.

cent. This rain continued with varying intensity until 8:20 p. m., the total recorded being 0.21 inch.

As far back as data extend there is no record of such abnormally high morning temperatures as occurred over southern California on the 17th. At the time of the readings, 4:40 a. m., San Diego reported 93.3°; Los Angeles, 90.3°; and the thermographs at El Cajon, Bonita, and Escondido showed 91.4°, 91.9°, and 92°, respectively.

We now know that these record temperatures and widely contrasting conditions were occasioned by the approach of a tropical cyclone that formed somewhere over the Pacific Ocean off the Mexican coast. Hurd has shown in his discussion, Tropical cyclones of the eastern north Pacific, reprinted on the backs of numerous editions of Pilot Charts, that such storms are by no means infrequent; that they attain great force, and sometimes move northward along the coast, recurving over northern Baja California or southern California.

For several days previous, dynamically heated winds prevailed over southwestern United States, due to an anticyclone of moderate intensity that was crested over the Plateau region, and a low barometric system over the Pacific slope. However, it was not until we could chart the movements of this Pacific cyclone that we were able to explain the causes that gave rise to the apparently inexplicable phenomena of rain with very low humidity and temperatures which were obviously the result of adiabatic heating.

The following translations of those portions of the Mexican maps that refer to this cyclone are illuminating:

September 10.—There are indications of a cyclonic disturbance to the south of the Isthmus of Tehuantepec which will probably cause bad weather between Sa'ina Cruz and Manzanillo.

September 11.—There are still indications of a cyclonic disturbance to the southwest of the port of Salina Cruz.

September 12.—To the southeast (? sureste) and near Acapulco indications of a cyclonic disturbance continue.

September 13.—To the southwest and near the port of Acapulco is located the cyclonic disturbance which has caused bad weather recently, and it is probable that it will move toward the region south of the Gulf of California.

September 14.—South of Manzanillo is found the cyclonic disturbance of the Pacific which appears to be moving toward the northeast.

September 15.—For lack of precise data it is not possible to know the position of the cyclone over the Pacific.

September 16.—The Pacific cyclone is found to the west and very near Mazatlan being probably between the land to the north and said port.

September 17.—We have no data of the Pacific cyclone, but the weather is becoming better rapidly in the region south of the Gulf of California.

September 18.—The cyclonic disturbance of the Pacific, almost dissipated, is found to the west of San Diego, Calif.

Gales and heavy rains occurred on the coast, and winds of hurricane force were reported at Manzanillo, Acapulco, and Mazatlan during the period from the 10th to the 14th.

A table showing the hourly changes in temperature, wind velocity and direction, and rainfall at San Diego and Los Angeles on the 17th, when the storm passed over southern California, is available for reference. Two days later the storm had completely disappeared.

The rainfall on the coast was light, but torrential falls occurred locally at points in the mountains, and considerable damage to property resulted.

SLEET AND SNOW AT UNUSUALLY HIGH TEMPERATURES

By J. P. McAuliffe

[Weather Bureau Office, Corpus Christi, Tex.]

An unusual phenomenon occurred at Corpus Christi, Tex. November 14, and was repeated on a smaller scale November 20, the occurrence of sleet and snow with the surface temperature above 50°.

Sleet began falling at 8 p. m. November 14, and continued intermittently until 10 p. m. The measured precipitation resulting from this sleet was nearly 0.004 of an inch. Several rather heavy showers of sleet fell during the 2-hour period, 8 to 10 p. m. The writer examined the sleet carefully, and there was no doubt that it was genuine sleet. Pellets remained unmelted for a few minutes after falling.

During the entire time this sleet was falling the surface temperature was above 50°. Temperature at 6:40 p. m. was 53°, after which there was a gradual fall to 50° at midnight. The sleet fell from alto-stratus clouds moving from the west. The surface wind was from the northwest.

Another slight fall of sleet and snow occurred during the morning of November 20. Snow fell in large flakes from 10:30 a. m. until 10:33 a. m., and sleet fell from 11:30 a. m. to 11:34 a. m. Surface temperature during the time of this fall was never below 57°, ranging from 57° at 6:40 a. m. to 58.5° at noon. The precipitation came from stratus clouds moving from the north-northeast. The surface wind was from the north.

The explanation of these unusual phenomena seems to be that a stratum of freezing air overspread Corpus Christi at the time of sleet and snowfall. In the case of the sleet November 14 the air at the altitude of the clouds must have been above freezing, while below this level considerably below freezing existed, and this layer of subfreezing air was probably not more than 1,000 feet above the ground.

DISCUSSION

It seems most likely that the sleet and snow at Corpus Christi was the result of a cold current aloft but at a considerably higher altitude than that suggested by Mr. McAuluffe, viz, 1,000 feet above the surface. Freezing temperatures at that height would have caused an extremely steep lapse rate (3° C./100 m.) which is not probable. The Groesbeck kite flight of November 14 shows a very variable lapse rate with temperatures around the freezing point from the surface to 2,525 m. above sea level. It would seem more probable that the sleet and snow at Corpus Christi came from a rather high elevation and evidently reached the surface before melting due to the near freezing temperatures encountered. Mr. H. L. Choate of the aerological division suggests the probability of the cooling effect of the evaporation of some of the snow and sleet as making it possible for the remainder to reach the ground. He recalls a similar condition at Drexel where sleet and snow fell, and the temperature to 3,800 m. remained above freezing.—*L. T. Samuels.*

CHEMICAL COMPOSITION OF RAINS AND SNOWS AT MOUNT VERNON, IOWA

By LAWRENCE KYNETT and JOHN LOHNER

[Cornell College, Mount Vernon, Iowa, September 17, 1929]

The analyses of the precipitations of rains and snows at Mount Vernon, Iowa, were made under the direction of Dr. Nicholas Knight, professor of chemistry at Cornell College. Altogether there were 46 samples studied from October 4, 1928, to June 9, 1929. There were 37 specimens of rain, 7 of snow, and 2 of both rain and snow.

The precipitations are collected in clean, granite pans, 17 inches in diameter, kept away from trees and buildings. The village, exclusive of the college, has a population of about 1,700, with no factories. The sulphuric acid must come mainly from the coal used in the private heating plants.

The methods employed in the analysis are taken from Standard Methods of Water Analysis, sixth edition, published by the American Public Health Association. The work has been carried on in a laboratory devoted exclusively to water analysis, in which no ammonia is allowed. In the test for chloride we have found it necessary to deduct 3.55 parts per million from the reading to allow for the formation of the color.

The precipitations usually come from the east or the south which signifies that the salt as represented by the chlorine is borne several hundred miles from the Atlantic Ocean or Gulf of Mexico. The salt spray caught by the winds is borne across the continent to the place of precipitation.

The distillation method for the free and albuminoid ammonia is employed. The phenolsulphonic method is used with the nitrates. Practically all of the samples were colorless. The results of the investigation are given in the following tables.

TABLE 2.—*Data from Table 1 converted into pounds per acre*

Date	Rain or snow [1]	Chlorine	Free ammonia	Albuminoid ammonia	Nitrate	Nitrite	Sulphate
Oct. 4	Rain, 0.5 inch	0.30	0.04	0.031	0.0008	Trace.	None.
12	Rain, 0.75 inch	.46	.0007	.04	.004	Trace.	None.
13	Rain, 0.6 inch	.33	.028	.006	.0003	Trace.	None.
16	Rain, 0.42 inch	.24	.033	.018	.0002	0.00002	None.
17	Rain, 0.7 inch	.32	.06	.032	.0003	None.	None.
19	Rain, 0.15 inch	.32	----	----	.0002	None.	None.
21	Rain, 0.33 inch	.17	.027	.0008	.0015	None.	None.
22	Rain, 0.6 inch	.17	.0005	.0005	.0003	None.	None.
28	Rain, 0.15 inch	.18	.0009	----	.001	----	None.
Nov. 1	Rain, 0.18 inch	.11	.0016	.013	.0008	.00002	None.
2	Rain, 0.92 inch	.034	.0004	.013	.004	.00001	None.
7	Rain, 0.42 inch	.16	.004	.005	.001	.0005	None.
9	Both; rain, 0.25 inch	.22	.08	.024	.00073	.000008	0.11
14	Rain, 0.20 inch	.065	.008	.014	.0009	.00025	.11
17	Rain, 1.8 inches	1.80	.61	.28	.01	Trace.	None.
30	Rain, 0.72 inch	.43	.288	.032	.0048	Trace.	None.
Dec. 2	Rain, 0.27 inch	.119	.054	.014	.0015	Trace.	.013
14	Rain, 0.8 inch	.00933	.049	.036	.0013	Trace.	None.
Jan. 6	Snow, 3 inches	.21	.26	.091	.011	Trace.	.048
9	Both; rain, 5 inches	.104	.18	.027	.034	Trace.	.31
14	Snow, 3 inches	.078	.041	.037	.0008	Trace.	.25
18	Snow, 4 inches	.10	.049	.021	.003	None.	.11
22	Rain, 0.3 inch	.052	.10	.030	.002	Trace.	.11
24	Snow, 4 inches	.043	.027	.0114	.003	None.	1.61
Feb. 8	Snow, 3 inches	.092	.014	.0064	.00011	.00022	.0008
Mar. 11	do	.032	.018	.016	None.	.0001	.00054
Mar. 19	Snow, 5 inches	0.26	0.027	0.020	0.00095	0.00008	0.35
20	Rain, 0.5 inch	.39	.036	.032	None.	.00005	.00039
Apr. 1	Rain, 0.8 inch	.36	.0006	.047	None.	.00007	.0033
11	Rain, 0.9 inch	1.28	.098	.053	.0102	.00008	.0092
16	Rain, 0.1 inch	.91	.0073	.0055	None.	.00091	.011
19	Rain, 0.2 inch	.32	.013	.011	None.	Trace.	.004
20	Rain, 1 inch	.91	.055	.041	None.	Trace.	.028
25	Rain, 0.5 inch	.325	.0319	.025	Trace.	Trace.	.0011
27	Rain, 0.15 inch	.14	.0122	.0095	Trace.	Trace.	.0016
30	Rain, 0.48 inch	.285	.035	.03	Trace.	Trace.	.0003
May 11	Rain, 0.08 inch	.10	.006	.0054	.0004	Trace.	.00003
14	Rain, 0.25 inch	.35	.020	.016	None.	None.	.00021
23	Rain, 0.35 inch	.20	----	----	None.	Trace.	.0002
23	Rain, 0.08 inch	.12	.0063	.004	None.	.00011	.003
27	Rain, 0.45 inch	.27	.034	.032	None.	Trace.	.003
29	Rain, 0.33 inch	.20	.026	.024	None.	Trace.	.026
29	Rain, 0.5 inch	.47	.037	.032	None.	Trace.	.00024
June 4	Rain, 0.25 inch	.22	.018	.016	None.	Trace.	.00021
9	Rain, 0.8 inch	.86	.058	.050	None.	Trace.	.0016

[1] 1 inch of rain on an acre weighs 226,875 pounds; 12 inches of snow the equivalent of inch of rain.

TABLE I.—*Parts per million*

Date	Rain or snow [1]	Chlorine	Free ammonia	Albuminoid ammonia	Nitrate	Nitrite	Sulphate
Oct. 4	Rain, 0.5 inch	2.64	0.3600	0.2800	0.007	Trace.	Absent.
12	Rain, 0.75 inch	2.69	.0400	.2400	.022	Trace.	Absent.
13	Rain, 0.6 inch	2.33	.2000	.0400	.002	Trace.	Absent.
16	Rain, 0.43 inch	2.69	.3600	.1120	.002	0.0002	Absent.
17	Rain, 0.7 inch	1.98	.3600	.2000	.002	Trace.	Absent.
19	Rain, 0.15 inch	1.98	[1]	[1]	.001	Trace.	Absent.
21	Rain, 0.33 inch	2.33	.3600	.1120	.002	Trace.	Absent.
22	Rain, 0.60 inch	1.27	.4000	.4000	.002	Trace.	Absent.
28	Rain, 0.15 inch	5.18	.2600	[2]	.030	[1]	Absent.
Nov. 1	Rain, 0.18 inch	2.69	.0400	.3200	.020	.0005	Absent.
2	Rain, 0.92 inch	1.63	.0400	.0500	.010	.0005	Absent.
7	Rain, 0.42 inch	4.11	.9600	.1600	.007	.00014	Absent.
9	Both, 0.25 inch	3.91	1.4400	.4400	.013	.00014	1.95
14	Rain, 0.20 inch	1.45	1.800	.4300	.020	.0056	Absent.
17	Rain, 1.8 inches	1.98	1.4800	.6800	.025	Trace.	Absent.
30	Rain, 0.72 inch	2.69	1.8000	.2000	.030	Trace.	Absent.
Dec. 2	Rain, 0.27 inch	1.98	.9000	.2400	.025	Trace.	0.21
14	Rain, 0.8 inch	1.37	.7200	.2000	.007	Trace.	Absent.
Jan. 6	Snow, 12 inches	.92	1.1300	.4000	.050	Trace.	.21
9	Both, 0.5 inch	.92	1.6000	.2406	.030	Trace.	2.71
14	Snow, 3 inches	1.37	.7200	.6400	.015	Trace.	4.46
18	Snow, 4 inches	1.37	.6400	.2800	.040	Absent.	1.47
22	Rain, 3 inches	.69	1.2800	.4000	.025	Trace.	.52
24	Snow, 4 inches	.56	.3600	.1500	.040	Absent.	2.12
Feb. 8	Snow, 3 inches	1.62	.2000	.1120	.002	.0004	.0073
Mar. 11	do	.56	.3200	.2800	Absent.	.0002	.0094
19	do	2.69	.2800	.2000	.001	.0008	3.67
25	Rain, 5 inches	3.41	.3200	.2800	Absent.	.0004	.034
Apr. 1	Rain, 0.8 inch	1.99	.3600	.2600	Absent.	.0004	.0183
11	Rain, 0.9 inch	6.25	.4800	.2600	.05	.0004	.045
19	Rain, 0.2 inch	7.1	.2800	.2400	Absent.	.0002	.0894
16	Rain, 0.1 inch	4.0	.3200	.2400	Absent.	.0004	.0469
20	Rain, 1 inch	4.0	.2400	.1800	Absent.	.0001	.076
25	Rain, 1.7 inches	[1]	.32000	.2800	[1]	[1]	[1]
25	Rain, 0.5 inch	2.85	.2800	.2200	.001	.0005	.0096
27	Rain, 0.15 inch	4.11	.3600	.2800	.001	.0001	.046
30	Rain, 0.48 inch	2.61	.3200	.2800	.001	.0001	.0026
May 11	Rain, 0.08 inch	5.46	.3400	.3000	.002	.0001	.0018
14	Rain, 0.25 inch	6.14	.3200	.2800	Absent.	Absent.	.0036
23	Rain, 0.35 inch	2.69	[1]	[1]	Absent.	.0001	.0029
23	Rain, 0.08 inch	6.55	.3500	.2000	Absent.	.0006	.0391
27	Rain, 0.45 inch	2.69	.3400	.2600	.001	.0002	.0045
29	Rain, 0.33⅓ inch	2.69	.3400	.3200	Absent.	.0001	.0034
29	Rain, 0.05 inch	4.1	.3200	.2800	Absent.	.0003	.0021
June 4	Rain, 0.25 inch	3.8	.2800	.2400	Absent.	.0002	.0036
9	Rain, 0.8 inch	4.8	.3200	.2800	Absent.	.0002	.0006

[1] Not enough sample. [2] Sample ruined.

AREAL RAINFALL ESTIMATES

By EDWARD N. WHITNEY, Consulting Engineer

[State Journal Building, Madison, Wis., November 13, 1929]

To obtain the most accurate estimate of the average rainfall on a given area, probably the best practice is to draw isohyetal lines and planimeter the areas under successive isohyetals. Judgment and personal equation, however, play a part in the drawing of these lines of equal rainfall, so that no two estimators get exactly the same results.

Since personal equation enters into the drawing of isohyetal lines, and since the time involved in drawing up and planimetering a long series of rainfall maps is considerable, it is evidently of benefit if a constant weight due to its location with respect to the drainage area and to other rainfall stations, can be applied to each rainfall station, which weight is of such a value that the resulting computations will give practically the same average rainfall, as would be obtained by the longer contour drawing and planimetering method.

In other words, if a weight can be given to each rainfall station as is done in the Thiessen method, but which takes into consideration the assumption of a straight-line variation of rainfall between stations, results will be obtained with the comparative ease of the Thiessen method and the accuracy that is obtained by drawing up a complete series of rainfall contour maps. The Thiessen method is explained by Robert E. Horton in the Engineering News Record for August 2, 1917, volume 79, page 211. Mr. Horton also describes the inclined-plane method for substituting missing data at rainfall stations. Continuing his line of reasoning, one arrives at the inclined plane or straight-line contour method of obtaining areal rainfall estimates.[1]

Briefly, the Thiessen method applies the rainfall at a station to all parts of the drainage area that are nearer to that station than to any other station. The drainage area is divided by first connecting stations by straight lines, then drawing perpendiculars at the center points of these connecting lines.

Figure 1 is a map of the drainage area of the Black River above Neillsville and Hatfield, Wis. Lines are drawn showing the division of the area according to the Thiessen method, and stations are also connected to form triangles which are the basis of the inclined-plane method. Three points determine each plane, and isohyetals in this case are made up of straight lines. Isohyetals are not actually made up of straight lines, but such planes and straight lines will produce a good average value for areal rainfall estimates. If the precipitation at one rainfall station is higher than that at surrounding stations, the average rainfall on an area near the first station will not be as large, when determined by straight-line contours, as by curved contours as usually drawn, but such a distinction is in most cases finer than the reliability of the original data warrants.

Questions will come up as to the formation of the triangle framework. Stanley and Marshfield are joined, since the distance between the two is slightly less than the distance between Medford and Neillsville. If thought necessary, both lines can be drawn, and the average effect of the four stations determined on the sum of areas 4 and 5. It appears difficult to reproduce contours to correspond to this average effect of the four stations in question, but average rainfall rather than contours is the object sought.

If we join Medford and Neillsville, straight-line variation of rainfall is better obtained through the drainage area than if the area is cut by a line between Stanley and Marshfield. It may be logically claimed that stations within a drainage area should be given more weight than

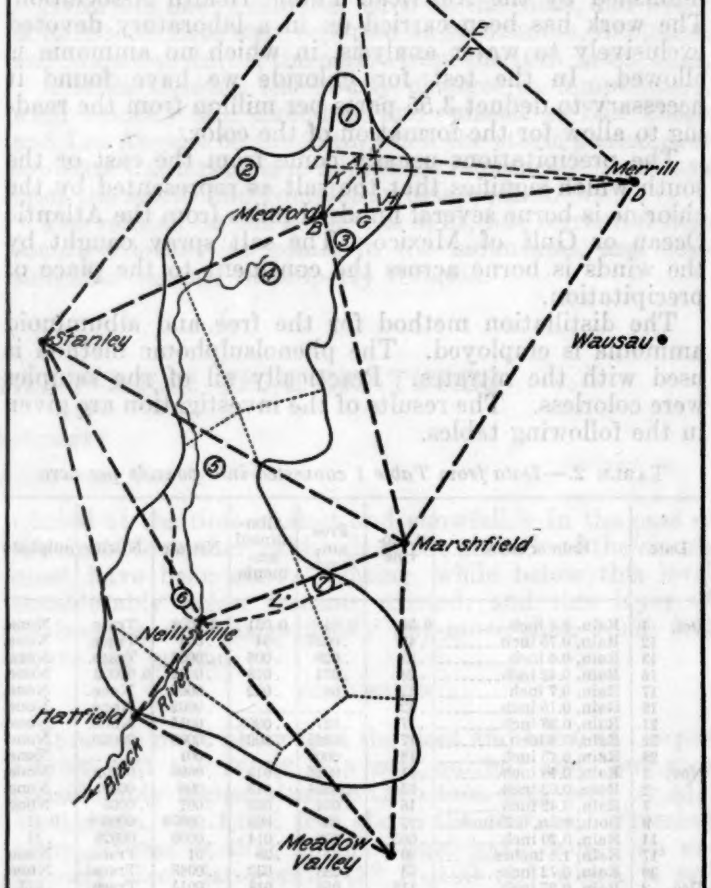

FIGURE 1.—Drainage area of the Black River above Neillsville and Hatfield, Wis.

stations outside of the area, but the simplest rule is to join by straight lines stations that are closer together than any other two stations.

It is probable that a strong triangle network should be sought giving triangles nearest to equilateral triangles in shape. Thus, it seems best to form triangles by connecting Neillsville with Meadow Valley, rather than by joining Hatfield with Marshfield, even if this second line is shorter than the first.

[1] See also the article by Robert E. Horton in MONTHLY WEATHER REVIEW, for June 1923, p. 296.

The objection to the Thiessen method is partly due to the ignoring of some stations outside of the drainage area. These outside stations are indicative of conditions to a certain extent and would be used if isohyetal lines were drawn. The inclined-plane method gives outside stations the weight to which they are entitled.

The drainage area above Neillsville is divided into seven parts by the triangles used in the inclined-plane method. The centers of gravity of each part are located by inspection or by any suitable method. The effect of the three surrounding stations is then determined on each center of gravity. If a triangle were entirely included within a drainage area, the effect of each of the three corner stations on the center of gravity of the triangle would be one third. On the drainage area above Neillsville this condition is not found.

On area No. 1, the center of gravity is at point *A*. The effect of Medford on point *A* and therefore on area No. 1 is proportional to the distance *AE* over the distance *BF*, or 0.74. The effect of Prentice equals *AG* over *CH*, or 0.14. Similarly the effect of Merrill is *AI* over *DJ*, or 0.12. The sum of these three constants is of course equal to 1.0. Instead of drawing the lines *AI*, *DJ*, etc., perpendicular to the sides of the triangle, lines may be drawn from each rainfall station straight through the center of gravity, *A*, to the opposite side of the triangle. The effect for Merrill on area No. 1 then becomes *AK* over *DK*, which is equal to *AI* over *DJ*.

Area No. 1 is 0.10 of the entire drainage area above Neillsville. The effect of Medford on the whole area as far as area No. 1 is concerned is 0.10 of 0.74, or 0.074. Similarly, the effect of Prentice is 0.014 and of Merrill is 0.012.

In the same way, figuring for each of the seven parts of the drainage area, the effects of each station are summed up to give the final constant for that station. The sum of the products of the rainfall at a station times its respective constant gives the average rainfall on the total drainage area. For small subdivisions of the drainage area such as 3, 6, and 7 the Thiessen method or a combination of the Thiessen and inclined-plane methods may be used. For area 3, Medford rainfall may be applied to all of area 3. For area 7, the effect of Meadow Valley may be ignored, and weight given only to Neillsville and Marshfield, in inverse ratio to their distances from the center of gravity of area 7 at point *L*.

Table 1 gives the constants obtained by the Thiessen method and by the inclined-plane method for the drainage area above Neillsville.

TABLE 1.—*Constants for areal rainfall estimates*

Rainfall station	Thiessen method	Inclined-plane method: With line joining Stanley and Marshfield	Inclined-plane method: With line joining Medford and Neillsville	Inclined-plane method: Average using both lines
Medford	0.571	0.369	0.522	0.447
Prentice	0	.041	.041	.041
Merrill	0	.012	.012	.012
Stanley	.104	.247	.113	.180
Marshfield	.070	.201	.050	.120
Neillsville	.255	.130	.262	.200
Hatfield	0	0	0	0
Meadow Valley	0	0	0	0
	1.000	1.000	1.000	1.000

This table shows that the effect of Prentice and Merrill is small, and that the effects of other stations differ considerably in the two methods. This difference may not alter the average rainfall greatly where annual rainfalls are used at the stations, but if monthly precipitation is used, which has a greater percentage of difference between stations, the average rainfalls obtained will differ to a greater degree than in the case of annual rainfall.

Annual rainfall run-off points were plotted for the drainage areas above Neillsville and above Hatfield on the Black River for the years 1915 to 1928, inclusive. Where the inclined-plane method of estimating the average rainfall on the drainage areas was used, improvement in the location of rainfall run-off points was shown. Apparently excessively high average rainfalls obtained by the Thiessen method were reduced when the inclined-plane method was used. In like manner, low average rainfalls were raised when the inclined plane method was applied.

The objection to the Thiessen method seems to be that we know that rainfall is not distributed uniformly over certain areas as the method assumes. We also know that average rainfall on an area is not perfectly described in terms of triangular planes, but we have more difficulty in proving how the rainfall distribution varies from this last assumption.

Other factors of course enter into rainfall distribution and amount such as altitude and direction of winds, but an alternation of the constants to allow for these conditions can be made if the estimator believes that he can make an improvement. If he obtains his original constants by methods that are the most logical, he will then have a solid foundation on which to base his later work.

A CORRELATION BETWEEN SOLAR RADIATION INTENSITIES AND RELATIVE HUMIDITIES

By P. R. GAST

[Harvard Forest and Northeastern Forest Experiment Station, November 7, 1929]

In the compilation of data on two synchronous studies of factors affecting tree growth and of weather and forest fire fuel relationships[1] a noteworthy relation between relative humidity and solar radiation intensity was discovered.[2] This relationship is not advanced to supplant other indices for the computation of probable radiation intensities, such as have been used with success by Kimball (*6*). It is advanced as a contribution to research on the relations between weather and ecological problems and forest fire-hazard studies in which are stressed short period information for all kinds of meteorological conditions including all degrees of cloudiness.

The solar radiation record was obtained by a spherical hot-junction thermopile devised by the writer (*2*) (*3*) to integrate all radiation at normal incidence. For the work here reported three of these thermopiles (type A(*3*)) in series were registered on an Engelhard RM recorder (*4*) giving 30 readings an hour. This material has been grouped in correlation tables which differ in the relative humidity data employed and the number of observations included. All the material available has been used; that the total hours do not equal all those possible is due to the absence of the observer on rainy days when the fire hazard was nil.

The crude data are presented in Table 1. In August and September, 1927, 172 three-hour records out of a possible 183 were obtained, so that a variety of sky conditions are represented. The gram calories per square centimeter for the 3-hour period are correlated with the relative humidity (by sling psychrometer) at the end of that period. The 8–11 a. m. (apparent time) radiation values are used with the 11 a. m. relative humidity (per cent), the 11 a. m.–2 p. m. radiation with the 2 p. m. relative humidity, the 2–5 p. m. radiation with the 5 p. m. relative humidity. From these data (correlation coefficient $r = -0.76$) may be calculated the regression equation of solar radiation on the relative humidity.

Solar radiation ($\sigma = \pm 36.85$) $= 306.0 - (2.678 \times$ relative humidity (in per cent)). The standard error σ includes two-thirds the readings.

From similar data for July 1 to August 20, 1926, inclusive, 141 periods, out of a possible 153 (see table 2), the following relation is obtained ($r = -0.75$):

Solar radiation ($\sigma = \pm 41.63$) $= 306.1 - (2.635 \times$ relative humidity (per cent)).

There is a loss in intensity of radiation due to the increasing air mass through which it must pass as the zenith hour angle of the sun increases. (Kimball (*5*) and (*6*).) No allowance for this factor entered into the values of the radiation used above. The need for such a correction can be reduced by retaining only the 11 a. m. (8–11) and 2 p. m. (11–2) periods. A further correction was made by substituting the average of the 11 a. m. and 2 p. m. relative humidity values for the single 2 p. m. relative humidity reading employed heretofore. In this way was obtained (table not given) a correlation coefficient $r = -0.80$ and the regression equation:

Solar radiation ($\sigma = \pm 30.93$) $= 311.4 - (2.543 \times$ relative humidity (per cent)).

The estimate of relative humidity used above may be further refined by checking the 11 a. m. and 2 p. m. readings of the hair hygrograph with the sling psychrometer and then estimating the integrated deviation of the trace. This deviation was applied to the average relative humidity. These values are entered in a diagram (Table 3). An $r = -0.84$ is obtained, and a regression equation.

Solar radiation ($\sigma = \pm 29.02$) $= 303.2 - (2.530 \times$ relative humidity (per cent)).

These two successive refinements, first, the correction for loss by absorption in increasing air mass, and second, the improvement in the value of relative humidity, show about the same improvement, 0.04, in the value of the correlation coefficient. The standard error is diminished 20 per cent by the isolation of values with a small variation in air-mass absorption.

Comparison of the correlation table (No. 3) for solar radiation and relative humidity ($r = -0.84$) with the correlation table (No. 4) for solar radiation and vapor pressure ($r = -0.31$) shows how large a factor is the atmospheric transmission. For it is by the association of the atmospheric temperature with the absolute atmospheric moisture that the resultant, the relative humidity, becomes significant when clear skies do not prevail.

For a check, the hair hygrograph record was planimetered for the average relative humidity between 8 a. m. and 5 p. m. for each day of August and September, 1927. The total solar radiations for the same 9-hour periods were computed and entered with them. (Table 5.) The calculations give the following ($r = -0.887$):

Solar radiation ($\sigma = \pm 71.4$) $= 875.2 - (7.60 \times$ relative humidity (per cent)).

Over the longer period of time and by use of a relative humidity value which is probably more accurate, a very good value for the correlation coefficient is obtained.

That cloudiness reduces the duration of sunshine is a commonplace daily observation. In the absence of clouds variation in vapor pressure is correlated with minor fluctuations in the radiation intensities. An empirical formula introducing the mean cloudiness was used by Kimball (*6*) to reduce the clear sky intensities to mean intensities. (See Ångström (*1*).)

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[1] These studies were common projects of the Northeastern Forest Experiment Station and the Harvard Forest. The meteorological data, other than solar radiation, were obtained by Mr. P. W. Stickel, in charge, and Mr. A. W. Gottlieb; planimeter records of solar radiation by Mr. Gottlieb; computations by Mr. Roy A. Chapman.

[2] There are certain well-known factors controlling the intensity of solar radiation at a given time and place, as follows:

(1) The distance of the earth from the sun.
(2) The zenith distance of the sun.
(3) The scattering of the solar rays by the gas molecules of the atmosphere, including water vapor.
(4) The selective absorption of solar rays by atmospheric gases, principally by water vapor.
(5) The scattering and absorption by atmospheric dust.
(6) The reflection from the upper surfaces of clouds.

The law of variation of each of these factors is well known, and the important factors are solar zenith distance, the water-vapor content of the atmosphere, which is determined through the absolute humidity, the dust content of the atmosphere, and the percentage of the sky covered with cloud.

It seems to be a coincidence that a high minus correlation exists between the relative humidity of the atmosphere and radiation intensity. With a clear sky the relative humidity generally decreases rapidly as the air temperature rises to its maximum for the day, and at approximately the same time the radiation intensity increases as the zenith distance of the sun decreases. Furthermore, the probability of the formation of lower clouds increases as the relative humidity increases and such clouds act as a reflector to turn back the incoming solar radiation. It thus appears that the relative humidity, which is an important factor in forest-fire hazard also gives an indication of the solar radiation intensity; but as the author points out, it can hardly be employed in computations of solar radiation intensity at a given time and place.—*H. H. K.*

The correlation values here derived for insolation intensities and relative humidity imply that some relation must exist between mean relative humidity and mean cloudiness for these periods. The writer has not been able to obtain data which could be examined for such a relation. That such a relationship is tacitly admitted, at least qualitatively, is apparent from the monthly discussions in the review of relative humidity and sunshine in the weather elements under the caption Weather in the United States.

If the quantitative relation here discussed is found to hold generally it will be useful in various sorts of ecological work. It will make possible the approximation of regional sunshine values for which observations on the mean cloudiness are not available. For public-health work the study of the relation of relative humidity to loss of radiation in the ultra-violet "biological band" is even more striking, as evidenced by some determinations (unpublished) of the writer.

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Table 1.—*Solar radiation for 3-hour period correlated with per cent relative humidity at end of period, August 1 to September 30, 1927*

[Three-hour periods are 8 to 11 a. m., 11 a. m. to 2 p. m., 2 to 5 p. m.]

Solar radiation, gr.=cal./cm². (3-hour periods)	Relative humidity (per cent)							
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	Total
213-237					4	2	1	7
188-212		1			7	7		15
163-187		1	4	3	20	9		37
138-162			7	5	13	2	1	28
113-137	1	3	5	4	7	1	1	22
88-112	2	2	9	8	4			25
63-87		3	3	1				7
38-62	4	2	5	1				12
13-37	13	5	1					19
Total								172

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Table 2.—*Solar radiation for 3-hour periods correlated with per cent relative humidity at end of period, July 1 to August 20, 1926*

[Three-hour periods are 8 to 11 a. m., 11 a. m. to 2 p. m., 2 to 5 p. m.]

Solar radiation, gr.=cal./cm². (3-hour periods)	Relative humidity (per cent)							
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	Tota
213-237					2	18	12	32
188-212				4	5	5	3	17
163-187			2	4	7	6		19
138-162			3	5	6	1	1	16
113-137	2		3	4	2	3		14
88-112	1	1	4	3	2	3	1	15
63-87	2	3	4	1	1			11
38-62	4	3			2			9
13-37	4	2		2				8
Total								141

Table 3.—*Solar radiation for the midday 3-hour period, 11 a. m. to 2 p. m., correlated with the relative humidity for the period determined from hygrograph record, August 1 to September 30, 1927*

Solar radiation, gr.=cal./cm². (3-hour periods)	Relative humidity (per cent)							
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	Total
225-249						1		1
200-224						2	2	4
175-199					9	7	1	17
150-174				5	4	4		13
125-149		2	1					3
100-124	2		2	1	3			8
75-99	1	1	3					5
50-74								0
25-49	2	3						5
0-24	1							1
Total								57

Table 4.—*Solar radiation for the midday 3-hour period, 11 a. m. to 2 p. m., correlated with the vapor pressure for the period determined from hygrothermograph record, August 1 to September 30, 1927*

[Compare with Table 3]

Solar radiation, gr.=cal./cm.² (3-hour periods)	Vapor pressure									
	0.749–0.700	0.699–0.650	0.649–0.600	0.599–0.550	0.549–0.500	0.499–0.450	0.449–0.400	0.399–0.350	0.349–0.300	0.299–0.250	Total
225-249									1		1
200-224								2		2	4
175-199				2			4	5	4	2	17
150-174	1		1	3	2	2	1	2	1		13
125-149				1	1		1				3
100-124	1			1	1	2	2			1	8
75-99				2			1	2			5
50-74											0
25-49	1			1		1	1		1		5
0-24								1			1
Total											57

Table 5.—*Solar radiation for the 9-hour period, 8 a. m. to 5 p. m., correlated with per cent relative humidity from integrated hygrograph record for period, August 1 to September 30, 1927*

Solar radiation, gr.=cal./cm². (9-hour periods)	Relative humidity (per cent)							
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	Total
578-640					1	3	2	6
515-577					1	7	2	10
452-514				4	6	2		12
389-451				3	2	1		6
326-388		1	3	1		1		6
263-325			4	1	2			7
200-262	1	3	2					6
147-199	3							3
84-146	2	2						4
21-83	1							1
Total								61

SOLAR RADIATION AND RELATIVE HUMIDITY IN RELATION TO DUFF MOISTURE AND FOREST FIRE HAZARD

By P. R. GAST, Harvard Forest and Northeastern Forest Experiment Station; and P. W. STICKEL, Northeastern Forest Experiment Station, Forest Service, November 7, 1929

The dependence of forest fire hazard on meteorological conditions is increasingly evident through the work of Plummer (*1*), Hoffman (*2*), Show (*3*), Gisborne (*4*), Stickel (*5*), and others. They have shown that among the various meteorological indices of increasing forest-fire danger a decreasing relative humidity is of large significance.

In all these studies stress is laid upon the gain and loss in the moisture of forest-fire fuels due to the equilibrium relations between them and the moisture in the atmosphere (4: p. 28–34). The source of the energy necessary to vaporize the water when it passes into the atmosphere has not been considered. Gisborne gave data for exposures to different totals of radiation (4: p. 22–35) and remarks that determination of variation in loss of moisture when only the amount of shielding from sunlight is varied would be valuable. But no clear-cut relation between radiant energy and duff moisture-content values was exhibited.

A relation discovered between solar radiation and relative humidity (7) led to a direct experimental investigation of the influence of radiation on the duff moisture of the very kind proposed by Gisborne.

An "open" station with a duff hygrometer was in continuous operation. Two additional plots of duff were covered with bobbinet cloth screens at a height of about 14 inches above the ground. The "2x" screen absorbed about 70 per cent, and passed an average of 30 per cent of the radiation; the "x" screen absorbed about 50 per cent and passed an average of 50 per cent of the radiation. Under each of the screens a duff hygrometer was placed to record the moisture content of the duff. Sets of thermopiles used with a recording galvanometer (6 and 7) integrated the radiation in the intervals between the readings at 8 a. m., 11 a. m., 2 p. m., and 5 p. m. At these hours the duff hygrometers were read, and the relative humidity of the air determined with a sling psychrometer. The height of the screens was sufficient to insure the same relative humidity and wind velocity of the air passing over the three duff sites.

These data for typical series of days are given in Table 1 and graphically in Figure 1. The series starts the third day after a rainfall of 0.96 inch on September 11, 1927. The previous 10 days, September 1 to 11, had been without rain so that the duff moisture in the open had averaged 5 per cent at 2 p. m.; at 2 p. m. on the 12th it was 7 per cent with a relative humidity of 41 per cent, and on the 13th, 10 per cent with a relative humidity of 66 per cent. On the 15th 0.14 inch of rain fell between 7 and 11 a. m.; the duff moisture in the open did not fall below 50 per cent. Between 5 p. m. on the 19th and 8 a. m. on the 20th, 1.27 inches of rain fell, so that under the "2x" cover the moisture content did not go below 50 per cent until 11 o'clock on the 22d. The graph therefore recommences with the 23d.

The data reveal the conditions found to be typical for the whole course of 60 days during which the experiment was continued; namely, that diminution in the radiation intensity incident upon the duff reduces the rate at which the duff moisture content decreases during the day.

By comparison of the relative-humidity values and the intensity in the "open" there is brought out here the relation between radiation intensity and relative humidity, which was discussed at length in a previous paper (7). A study of 313 three-hour records showed that the lower the relative humidity the greater the radiation intensity. It is believed that the screens used in this experiment and cloudiness of the sky produce the same result in slowing the drying out of the duff by a common effect of diminished radiation intensities.

Further analysis presents additional information on the importance of radiation intensity. The variations in the daily march of radiation intensity may be divided into three groups. The typical day is represented by September 14, 24, 25, and 26. On these days the 11 a. m. to 2 p. m. radiation intensity is the greatest, and the 8 a. m. to 11 a. m. and the 2 p. m. to 5 p. m. values of radiation intensity are smaller. The 27th of September was also characterized by a midday maximum, but the radiation intensities were of a different and lower order because of the higher relative humidity. A second group with radiation intensities diminishing through the day is represented by September 16, 18, and 23. The third group with radiation intensity increasing through the day is represented by September 17.

The first group of days with a midday maximum of radiation intensity shows a minimum duff moisture at 2 p. m. As the radiation intensity decreases in the afternoon, the duff moisture increases.

On the 16th, the gradually decreasing radiation started from an extraordinarily high 8 a. m. to 11 a. m. radiation intensity, with an 11 a. m. to 2 p. m. intensity almost as great. September 16 also shows minimum duff moisture at 2 p. m. On the other days there was either an increase of duff moisture as on the 18th, or a small decrease of duff moisture as on the 23d.

On the 17th there was a relative humidity march as on the typical day with a minimum relative humidity at noon. But because of an increasing radiation intensity, the duff moisture drops continuously until 5 p. m.

For the understanding of this phenomenon it will be necessary to consider not only the moisture outgo but the moisture income of the materials in the fuel horizons. Gisborne (4: p. 22) classified three sites as moist, medium, and dry. From the context it is evident that he was considering the conditions of exposure and evaporation rate, in addition to any differences in ground water movements and supply. For clarification of the research on forest fuel relationships, it will be important to classify sites solely on the rates at which they supply water to the fuel horizons.

In view of our experiments, and certain experiments cited by Stockbridge (8), a logical inference is to consider the duff as a level in which the water vapor is condensed from the upward-moving soil air. The small amount of energy thus liberated tends to raise the temperature of the duff but is radiated away into space. With an input of radiation at a given constant value, the duff moisture received from lower soil horizon is evaporated about as fast as it is condensed, and the equilibrium of duff moisture content maintained at a low value. If the radiation intensity is increased, and the duff moisture income is unchanged, the rate of evaporation is increased, with the result that a lower duff moisture equilibrium is reached. A decrease in radiation intensity diminishes the rates of evaporation, and a higher duff moisture equilibrium is maintained. In a like manner, any alteration in the rate of moisture supply from the

lower soil horizons will, if the radiation intensity is unchanged, result in a new equilibrium for the duff moisture content. Evidence for this is obtained in a comparison of the duff moistures for three days, September 24, 25, and 26. No rain had fallen since the 20th, and since that time the soil had become progressively drier. The constant diminution in the rate of water supply to the duff horizon is reflected in the daily drying curve. The march of the relative humidity curves and the totals of radiations for the same hours of the three days are strikingly similar. Yet on each succeeding day the fuel material shows an earlier desiccation although the equilibrium values are about the same. The difference between the moisture contents of the duff in the open on the 25th and 26th, 30 as against 36 per cent respectively, is due to the smaller radiation intensity before 8 a. m. on the 26th. From dawn to 8 a. m. on the 25th the total radiation in the open was 61 gr.-cal per sq. cm., on the 26th it was 50 gr.-cal per sq. cm. for the same period. When compared with the three preceding days the march of the drying curve of the duff on the 27th is exceedingly instructive. Since there has been no rainfall the different values of radiation intensity alone must be responsible for the difference in moisture contents. The rate of water supply from the soil on the 27th is apparently about the same as on the 17th. With a radiation intensity in the open on the 27th very much like that under the "x" canopy on the 17th we find that the 2 p. m. readings of duff moisture are very much alike, 18 per cent and 21 per cent respectively. Under the canopies the radiation intensities were not sufficient to reduce the equilibrium moisture contents below 50 per cent.

TABLE I.—*September, 1927*

	11	12	13	14			15	16			17			18		
	Daily total	Daily total	Daily total	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.	Daily total	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.
Radiation, gm.-cal. cm. 2 — 2x[1]				45	45	23		63	68	40	18	30	46	57	41	1
Radiation, gm.-cal. cm. 2 — X				63	88	75		100	93	75	26	37	49	82	52	2
No shade	248	727	240	124	175	150	347	200	187	151	53	75	98	164	104	4

	2 p. m.	2 p. m.	2 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.	2 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.
Relative humidity, per cent	83	41	66	91	53	62	79	68	74	56	48	66	88	79	69	87	86	56	70	88
Duff moisture, per cent — 2x			24	50	31	21	25	50	50	26	17	22	50	50	35	29	50	26	25	36
Duff moisture, per cent —			18	50	21	15	17	50	50	20	12	12	50	38	21	15	50	18	17	27
No shade	50	7	10	50	10	8	10	50	50	13	6	8	35	22	12	10	36	8	9	14
Duff temperature, °F — 2x			67	60	71	70	64	67	66	68	72	69	58	63	68	67	[2]80	75	69	66
Duff temperature, °F — X			65	62	78	76	67	68	61	73	79	79	61	67	74	71	67	82	72	68
No shade	76	116	84	68	102	94	71	94	64	111	118	75	66	76	96	75	72	115	78	71
Vapor pressure inches hg	0.536	0.277	0.417	0.402	0.334	0.417	0.432	0.432	0.334	0.334	0.347	0.387	0.402	0.432	0.448	0.517	0.448	0.465	0.499	0.575
Rain, inches	0.96							0.14												

	19	20	21	22	23			24			25			26			27		
	Daily total	Daily total	Daily total	Daily total	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.	8-11 a. m.	11 a. m.-2 p. m.	2-5 p. m.
Radiation, gm. cal.-cm. 2 — 2x[1]					45	40	10	46	58	20	48	55	20	47	56	19	13	12	8
Radiation, gm. cal.-cm. 2 — X					75	56	20	78	90	72	72	85	52	72	84	52	16	20	10
No shade	58	536	448	423	151	113	40	154	180	145	145	171	109	143	169	105	32	41	11

	2 p. m.	2 p. m.	2 p. m.	2 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.	8 a. m.	11 a. m.	2 p. m.	5 p. m.
Relative humidity, per cent	99	45	53	54	79	55	51	79	73	55	43	76	76	53	53	66	78	51	42	79	94	85	79	81
Duff moisture, per cent — 2x	50	50	50	37	50	50	33	41	50	50	26	28	50	36	25	29	50	33	24	29	50	50	50	50
Duff moisture, per cent —	50	50	31	17	50	23	18	25	50	25	15	16	50	23	16	18	50	18	14	17	50	50	50	50
No shade	50	23	7	6	34	9	8	11	34	9	5	7	30	8	6	8	36	6	6	8	35	29	18	18
Duff temperature, °F. — 2x	58	66	66	62	55	64	60	56	54	63	64	58	54	66	69	61	58	71	72	62	53	54	56	54
Duff temperature, °F. — X	59	70	71	67	58	76	63	58	58	74	75	66	58	78	78	65	63	82	81	68	56	58	61	56
No shade	58	103	102	84	59	105	83	59	62	104	107	71	61	108	110	66	60	116	114	66	58	67	73	57
Vapor pressure, inches hg	0.417	0.310	0.360	0.322	0.334	0.310	0.298	0.347	0.310	0.310	0.277	0.334	0.322	0.360	0.417	0.373	0.387	0.417	0.373	0.432	0.387	0.347	0.347	0.310
Rain, inches	0.93	0.34																						

[1] The solar radiation intensities under the X canopy are taken to be equal to 50 per cent of the intensity in the open and are therefore only approximate figures. This transmission value of 50 per cent was determined by discontinuous observations during the period given here, and by continuous observations made before and after the dates cited.

[2] Low altitude sun underneath canopy on thermometer.

These experiments, by direct evidence, support the assertion of Lamb (9) that quick regrowth is an important factor in reducing fire hazard on cut-over areas. The importance of such growth is shown to be in its shading effect. Any interference with wind must be of secondary importance.

The complementary effects of leaves and relative humidity are also significant in studying the seasonal change in fire hazard. In southern New England there is a period of average low relative humidity before the leaves develop on the broad-leaf trees. High radiation intensities are observed, and the fire hazard is the greatest of any time in the year. After the appearance of the green leaves the fire hazard diminishes; with the summer rise in relative humidity a further decrease in forest fire hazard results.

For the prediction of fire hazard the relations discovered between relative humidity, solar radiation intens-

ity, cloudiness, and forest-fire hazard suggest the importance of a cloud "weather eye" to patrolmen. By estimation of the cloudiness, the probable hazard can be estimated. By summation of the average cloudiness since the last rainfall a better estimate of its effect on reducing the fire hazard is probable. The mean cloudiness of a given region will aid in relating the hazard in that region as compared with other regions. Similarly, the amount of given cover on a cut-over area will be an important criterion of the hazard it presents.

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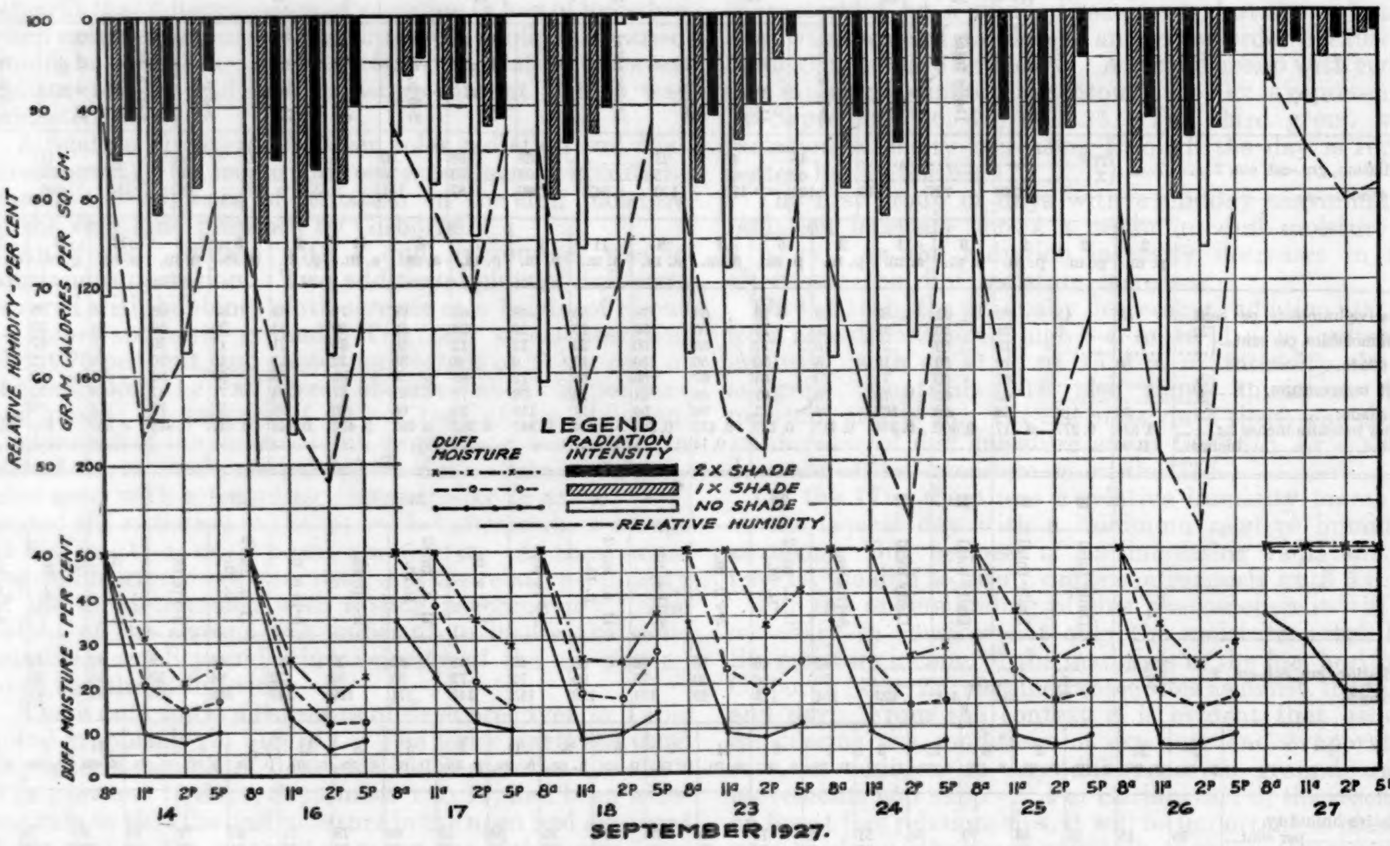
FIGURE 1.



DURATION OF RAINFALL AT HAVRE, MONTANA

By FRANK A. MATH

[Weather Bureau Office, Havre, Mont., October 23, 1929]

As the duration of precipitation in various parts of the United States is of much interest to forecasters, aviators, farmers, and business men in general, and as information of the kind so far published is for stations in the Atlantic States, it seemed desirable to prepare the data for a station in the semiarid plains region of the far Northwest.

The duration of precipitation for each hour during the 10-year period 1919–1928 was compiled for Havre, Mont., and entered on suitable forms. One form holds a month's record. All beginnings and endings of precipitation were considered and all intervals between rains were eliminated. The total for each day in hours and tenths were counted. Then the monthly totals were computed. Two compilations were made. The first, Table No. 1, includes every occurrence of precipitation recorded on Form 1014; the second, Table No. 2, includes only the hours in which 0.01 inch or more was recorded.

During the winter season in this section from November 1 to April 1, practically all of the precipitation occurs in the form of snow, and automatic registration is impracticable. Since the winter 1926–27 the observer has estimated the hourly amounts of snow as it fell during the awake hours. Previous to that time the hourly amounts, for this paper, were estimated as well as possible from the beginnings and endings and the 12-hour amounts. There are many times during zero weather in winter

that light fluffy dry snow falls continuously for 12 to 24 hours, amounting to only a trace or 0.01 inch, the last hour usually being credited with the 0.01. When more than 0.01 was recorded the amount was reasonably distributed throughout the period.

In the 10-year period which was tabulated it was found that the average total precipitation hours for the year is 720 when traces are counted and only 386 when traces are omitted. This indicates that for the total time precipitation occurs at Havre, slightly more than half (54 per cent) is at the rate of only a trace an hour. There are considerably more hours in winter with only a trace than in summer. During the cold months, October to March, inclusive, the average total precipitation hours including traces are 412, while those with 0.01 inch or more are 180, or 232 hours of only a trace. On the other hand, the warm months, April to September, inclusive, show 308 hours with traces included and 206 with traces omitted, or only 102 trace hours. Also during the warm six months with a normal rainfall of 10.27 inches the duration averages 308 hours, including traces, whereas during the cold six months with a normal precipitation of only 3.63 inches the duration averages 412 hours, which is 104 hours more time and 6.64 inches less precipitation. However, from Table No. 2, counting only hours with 0.01 or more, the summer half year averages 206 hours against 180 hours in the winter half. This conforms with statements by Henry and Tannehill (MONTHLY WEATHER REVIEW, April, 1929, p. 139): "The intensity of precipitation is greatest in warm months and least in cold months." Also, "A greater time is required for a given amount of rain to fall in cold periods than in warm, and the period of attendant cloudiness is extended."

An inspection of the monthly averages, Table No. 2, reveals that the peak of greatest duration of precipitation occurs during the month of June. This is also the wettest month. From the June peak there is a rapid falling off during July and August, which, however, is followed again by a sudden increase in precipitation hours during September. Then another low period in October, known as Indian summer, precedes the winter snows. Inhabitants living in this section for a number of years look forward to the September rainy period, which is usually accompanied by a cool spell with probably snow. It is generally attended by frosts and freezing.

A further study shows the duration of precipitation at Havre is extremely variable at all seasons. For a typical winter month, as January, the total number of precipitation hours, trace hours omitted, ranges from 10 to 61 hours; May, from 6 to 162 hours; July, from 5 to 42 hours; November, from 0 to 75 hours. The greatest monthly number of precipitation hours in the 10-year period was 162 in May, 1927, the least 0 in November, 1925. The greatest annual number was 559, in 1927, and the least 301, in 1928.

Computing percentages for Tables Nos. 1 and 2 and tabulating the results, precipitation is occurring at Havre on the average during the year as follows:

	Per cent											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Trace hours included	8.9	10.6	10.8	9.3	8.0	8.7	4.2	3.6	8.3	5.3	9.2	11.7
Trace hours omitted	3.9	4.6	4.8	5.4	5.5	6.5	3.1	2.5	5.2	2.3	4.6	4.7

By making a tabulation showing the average duration of precipitation, trace hours omitted (Table No. 3), throughout the 24 hours of the day in the different months for the 10-year period, also for the warm half of the year (April–September, inclusive, Table No. 4) and the cold half (October–March, inclusive, Table No. 5), it is found that during the warm six months, which period is the growing season, and most of the rains were registered by the automatic tipping bucket rain gage, the duration of precipitation is greatest for the hour 11 p. m. to midnight. It is twice as long as in the hour from 2 to 3 p. m. There is remarkably greater length of precipitation time during the night hours from 7 p. m. to 4 a. m. than during the daylight hours. While the hour from 2 to 3 p. m. has the least duration, the other afternoon hours between noon and 7 p. m. have considerably less than the night hours. This shows that there is a predominance of nighttime precipitation hours over daytime in this section. Kincer has shown (vol. 44, MONTHLY

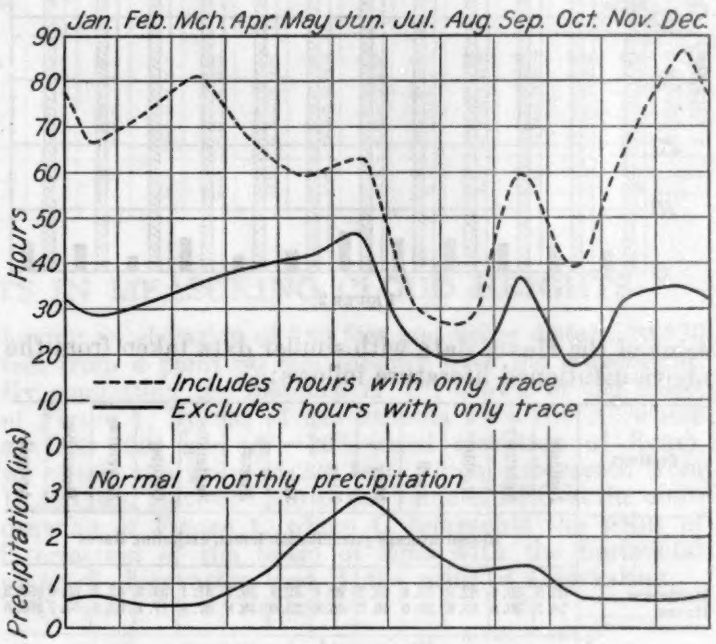


FIGURE 1

WEATHER REVIEW, 1916, pp. 628–633) that such is true generally for the summer season in the Central Plains region. This is probably due, to a great extent, to the large diurnal range in temperature over the plains. The rapid rise in temperature shortly after sunrise expands the air to such a degree that the moisture content is readily absorbed. The relative humidity falls to a low point during the daytime hours.

The duration during the winter half of the year is more uniform during the 24 hours. While the summer period ranges from 1.0 between 2 and 3 p. m. to 2.0 between 11 p. m. and midnight, the winter season ranges from 1.0 between 9 and 10 a. m. to 1.5 between 7 and 10 p. m. During the winter season there is no automatic hourly registration. The diurnal range in temperature is not so pronounced.

Figure No. 2 shows a comparison of the percentage of rainy hours with those of bright sunshine. Sunny weather occurs at Havre thirteen times as much of the possible time as rainy weather. It must be remembered also that, while rain may occur any time during the 24

hours, sunshine is limited to the hours that the sun is above the horizon, or about one-half of the time. The rainfall percentage of possible for the year is 4.4, while the sunshine hours total 58 per cent of the possible.

Other data on the duration of precipitation have been published for two Atlantic seaboard stations—Baltimore, by Nunn, in MONTHLY WEATHER REVIEW, February, 1929, and Philadelphia, by Mindling, in MONTHLY WEATHER REVIEW, November, 1918. A comparison of

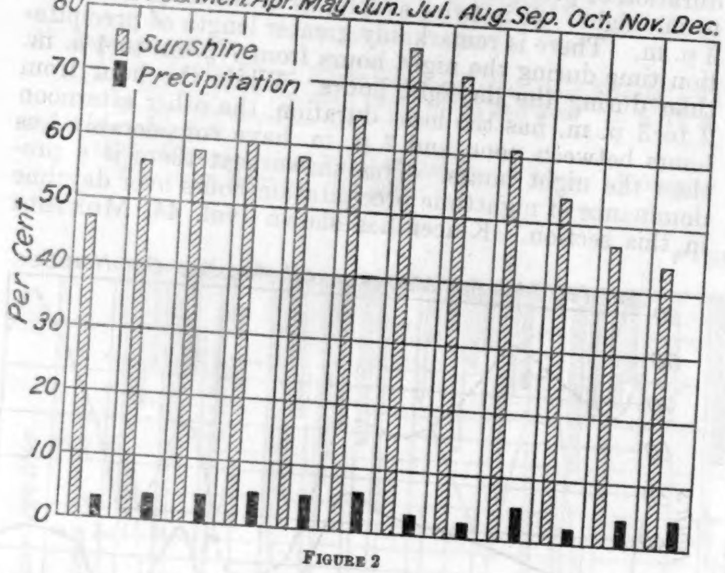


FIGURE 2

some of the Havre data with similar data taken from the above-mentioned literature follows:

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	10-year average precipitation hours, excluding traces												
Baltimore	63.9	59.0	62.9	57.4	44.2	29.4	32.3	39.7	31.1	34.5	42.3	60.5	557.2
Havre	28.7	30.8	35.6	39.0	40.7	46.8	23.0	18.8	37.1	17.1	33.1	34.7	385.6
	Daily average												
Baltimore	2.1	2.1	2.0	1.9	1.4	1.0	1.0	1.3	1.0	1 1	1.4	2.0	1.5
Havre	0.9	1.1	1.1	1.3	1.3	1.6	0.7	0.6	1.2	0.6	1.1	1.1	1.1

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	10-year average precipitation hours, including traces												
Philadelphia	119.1	108.0	103.1	101.0	76.0	59.8	41.0	54.6	46.5	59.3	70.0	101.7	940.1
Havre	66.3	72.1	80.6	67.2	59.5	62.8	31.0	27.1	60.0	39.6	66.5	87.0	719.7
	Daily average												
Philadelphia	3.8	3.5	3.3	3.3	2.4	1.9	1.3	1.8	1.5	1.9	2.3	3.3	-----
Havre	2.1	2.6	2.6	2.2	1.9	2.2	1.0	0.9	2.0	1.3	2.2	2.8	-----

The greatest monthly number of precipitation hours, omitting traces, in the 10-year period for Baltimore was 114 hours, during April, 1918; Havre, 162 hours, May, 1927; the least for Baltimore, 1.8 hours, October, 1924; Havre, 0, November, 1925. The greatest annual number of hours for Baltimore was 637, in 1920; Havre, 559 in 1927; and the least for Baltimore was 502 in 1925; Havre, 301 in 1928.

As was expected the duration of precipitation at Havre, as a rule, is much shorter than at the Atlantic stations, however, there is a peculiar exception during the months of June and September, when Havre shows greater duration.

ACKNOWLEDGMENT

Mr. Roscoe Nunn read the manuscript of this paper and offered a few suggestions, which were followed.

TABLE No. 1.—*Total duration (hours) of precipitation at Havre, Mont., excluding hours with only traces, 1919 to 1928, inclusive*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1919	21.2	80.2	57.2	15.0	24.2	29.5	4.4	10.8	36.5	40.2	41.6	17.0	377.8
1920	61.3	24.4	34.6	87.0	36.1	31.2	16.9	20.3	19.4	19.9	2.6	34.0	387.7
1921	10.0	10.4	84.2	36.5	41.0	27.9	43.3	5.4	56.0	2.8	55.1	19.0	391.6
1922	36.2	52.2	29.4	42.3	60.6	26.1	35.2	7.0	23.1	5.0	42.2	37.0	396.3
1923	32.1	18.7	4.4	47.8	21.1	67.1	34.5	22.1	19.1	9.7	9.0	22.4	308.0
1924	25.8	26.0	54.1	31.1	25.4	70.8	13.7	12.7	23.8	15.4	34.0	70.9	403.7
1925	31.3	28.0	43.0	54.8	9.8	71.9	16.3	20.8	81.8	34.6	0.0	31.0	423.3
1926	17.0	16.0	4.5	6.6	20.9	38.0	5.1	23.7	78.0	2.8	70.1	24.5	307.2
1927	39.0	41.0	23.9	38.7	161.8	26.4	42.9	13.4	22.1	30.4	74.8	45.0	559.4
1928	13.4	11.0	21.2	30.5	6.5	79.6	18.2	51.6	11.1	9.8	2.0	45.8	300.6
Means	28.73	30.79	35.64	39.03	40.74	46.85	23.05	18.78	37.09	17.06	33.14	34.66	385.56
Per cent	3.9	4.6	4.8	5.4	5.5	6.5	3.1	2.5	5.2	2.3	4.6	4.7	-----

TABLE No. 2.—*Average total duration (hours) of precipitation, excluding traces, Havre, Mont., 1919–1928*

Month	A. M. 1	2	3	4	5	6	7	8	9	10	11	Noon	P. M. 1	2	3	4	5	6	7	8	9	10	11	Midnight	Total
January	1.7	1.6	1.5	1.1	0.7	0.7	0.7	0.5	0.9	1.0	1.4	1.3	1.2	0.8	1.4	0.8	1.3	1.0	1.1	1.2	1.6	1.9	1.5	2.0	28.73
February	0.8	1.1	1.1	1.5	1.4	1.2	1.1	1.0	1.2	0.8	1.3	1.2	1.2	0.8	0.9	1.2	1.4	1.5	1.8	1.9	1.8	1.7	1.7	1.2	30.79
March	1.7	1.8	1.6	1.6	2.1	1.5	1.1	1.1	1.0	1.3	1.2	1.1	0.9	1.7	1.2	1.0	1.4	1.3	1.4	2.1	1.7	1.9	2.0	1.9	35.64
April	1.8	2.2	2.1	2.1	1.7	1.4	1.4	1.6	1.4	1.4	1.2	1.6	1.2	1.2	1.2	1.4	1.0	1.2	1.4	1.9	1.7	2.2	2.2	2.5	39.03
May	2.1	2.1	1.6	1.7	1.4	1.8	1.0	1.4	1.3	1.7	1.4	1.4	1.2	1.2	1.1	1.4	2.1	2.1	1.6	2.5	1.9	2.3	2.2	2.1	40.74
June	2.2	2.3	2.2	2.4	2.1	1.9	2.0	1.8	2.0	1.4	1.3	1.4	1.5	2.0	1.5	1.6	1.8	1.9	1.6	1.9	2.3	2.5	2.8	2.4	46.85
July	1.7	1.4	1.4	1.2	0.7	0.7	0.8	1.0	0.9	0.7	0.7	0.8	0.6	0.7	0.6	0.9	0.6	0.6	0.5	1.2	1.2	1.1	1.3	1.8	23.05
August	0.8	1.0	1.0	0.9	0.8	0.9	0.8	0.8	1.0	0.8	1.0	0.8	0.5	0.6	0.2	0.4	0.6	0.7	0.6	0.9	0.8	1.1	1.0	0.7	18.78
September	1.9	1.7	1.8	1.7	1.8	1.9	1.5	1.6	2.2	1.5	1.3	1.2	1.5	1.1	1.1	1.2	1.2	1.0	1.0	1.5	1.6	1.6	1.9	2.2	37.09
October	0.5	0.7	0.6	0.9	0.7	1.0	1.1	0.7	0.7	0.8	0.8	0.7	0.5	0.8	0.6	0.7	0.6	0.7	0.7	0.8	0.6	0.7	0 9	0.4	17.06
November	0.6	0.7	1.5	1.7	2.0	1.1	1.3	1.5	1.5	1.3	1.4	1.9	1.6	2.0	1.8	1.5	1.6	1.3	1.4	1.1	1.4	1.4	0.8	0.9	33.14
December	1.3	1.3	1.4	1.4	1.7	1.4	1.7	1.6	1.3	1.1	1.0	1.6	1.6	1.1.	1.6	1.4	1.6	1.3	1.0	2.0	1.8	1.5	1.6	1.3	34.66
Total	17.1	17.9	17.8	18.2	17.1	15.5	14.5	14.6	15.4	13.8	14.0	15.0	13.5	14.0	13.2	13.5	15.2	14.6	14.1	19.0	18.4	20.0	19.9	19.4	-----
Mean	1.4	1.5	1.5	1.5	1.4	1.3	1.2	1.2	1.3	1.2	1.2	1.2	1.1	1.2	1.1	1.1	1.3	1.2	1.2	1.6	1.5	1.7	1.7	1.6	-----

TABLE NO. 3.—*Duration of precipitation (hours) during the crop growing season at Havre, Mont., April 1, to September 30, trace hours omitted (automatic registration)*

Month	A. M.												P. M.												Total
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Midnight	
April	1.8	2.2	2.1	2.1	1.7	1.4	1.4	1.6	1.4	1.4	1.2	1.6	1.2	1.2	1.2	1.4	1.0	1.2	1.4	1.9	1.7	2.2	2.2	2.5	39.03
May	2.1	2.1	1.6	1.7	1.4	1.8	1.0	1.4	1.3	1.7	1.4	1.4	1.2	1.2	1.1	1.4	2.1	2.1	1.6	2.5	1.9	2.3	2.2	2.1	40.74
June	2.2	2.3	2.2	2.4	2.1	1.9	2.0	1.8	2.0	1.4	1.3	1.4	1.5	2.0	1.5	1.6	1.8	1.9	1.6	1.9	2.3	2.5	2.8	2.4	46.85
July	1.7	1.4	1.4	1.2	0.7	0.7	0.8	1.0	0.9	0.7	0.7	0.8	0.6	0.7	0.6	0.9	0.6	0.6	0.5	1.2	1.2	1.1	1.3	1.8	23.05
August	0.8	1.0	1.0	0.9	0.8	0.9	0.8	0.8	1.0	0.8	0.8	0.8	0.5	0.6	0.2	0.4	0.6	0.7	0.6	0.9	0.8	1.1	1.0	0.7	18.78
September	1.9	1.7	1.8	1.7	1.8	1.9	1.5	1.6	2.2	1.5	1.3	1.2	1.5	1.1	1.1	1.2	1.2	1.0	1.0	1.5	1.6	1.6	1.9	2.2	37.09
Sum	10.5	10.7	10.1	10.0	8.5	8.6	7.5	8.2	8.8	7.5	6.9	7.2	6.5	6.8	5.7	6.9	7.3	7.5	6.7	9.9	9.5	10.8	11.4	11.7	------
Mean	1.8	1.8	1.7	1.7	1.4	1.4	1.2	1.2	1.5	1.2	1.2	1.2	1.1	1.1	1.0	1.2	1.2	1.2	1.1	1.6	1.6	1.8	1.9	2.0	------

TABLE NO. 4.—*Duration of precipitation (hours) during the winter season, at Havre, Mont., October 1 to March 31, trace hours omitted (hourly amounts estimated)*

Month	A. M.												P. M.												Total
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Midnight	
October	0.5	0.7	0.6	0.9	0.7	1.0	1.1	0.7	0.7	0.8	0.8	0.7	0.5	0.8	0.6	0.7	0.6	0.7	0.7	0.8	0.6	0.7	0.9	0.4	17.06
November	0.6	0.7	1.5	1.7	2.0	1.1	1.3	1.5	1.5	1.3	1.4	1.9	1.6	2.0	1.8	1.5	1.6	1.3	1.4	1.1	1.4	1.4	0.8	0.9	33.14
December	1.3	1.3	1.4	1.4	1.7	1.4	1.7	1.6	1.3	1.1	1.0	1.6	1.6	1.1	1.6	1.4	1.6	1.3	1.0	2.0	1.8	1.6	1.6	1.3	34.66
January	1.7	1.6	1.5	1.1	0.7	0.7	0.7	0.5	0.9	1.0	1.4	1.3	1.2	0.8	1.4	0.8	1.3	1.0	1.1	1.2	1.6	1.9	1.5	2.0	28.73
February	0.8	1.1	1.1	1.5	1.4	1.2	1.1	1.0	1.2	0.8	1.3	1.2	1.2	0.8	0.9	1.2	1.4	1.5	1.8	1.9	1.8	1.7	1.7	1.2	30.79
March	1.7	1.8	1.6	1.6	2.1	1.5	1.1	1.1	1.0	1.3	1.2	1.1	0.9	1.7	1.2	1.0	1.4	1.3	1.4	2.1	1.7	1.9	2.0	1.9	35.64
Sum	6.6	7.2	7.7	8.2	8.6	6.9	7.0	6.4	6.6	6.3	7.1	7.8	7.0	7.2	7.5	6.6	7.9	7.1	7.4	9.1	8.9	9.2	8.5	7.7	------
Mean	1.1	1.2	1.3	1.4	1.4	1.2	1.2	1.1	1.1	1.0	1.2	1.3	1.2	1.2	1.2	1.1	1.3	1.2	1.2	1.5	1.5	1.5	1.4	1.3	------

UTILIZATION OF FIXED SEARCHLIGHTS IN MEASURING CLOUD HEIGHTS

By IRVING F. HAND

[Weather Bureau, Washington, November 6, 1929]

For the past few weeks the writer has been making cloud-height determinations by means of the angular measurement of the location of a spot of light cast upon clouds by a powerful searchlight. The merit of the method, if there be any, lies in the simplicity, rapidity, and accuracy of the measurements, as the cloud height at any given time may be determined in less than a minute.

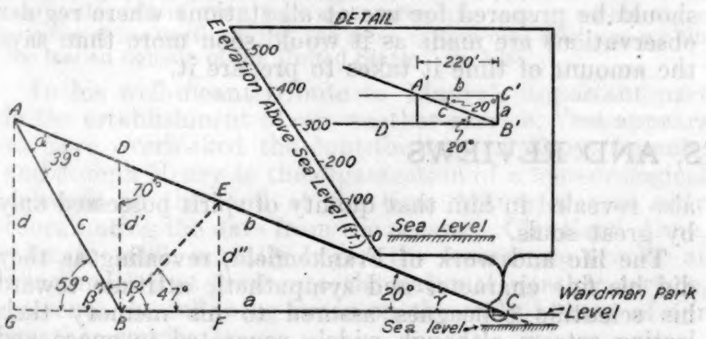


FIGURE 1.—Triangle formed by base line, BC, light beam, CA, and line of sight, BA

The searchlight utilized for this purpose is at an elevation of 300 feet on top of the Wardman Park Hotel, District of Columbia, and swings in a circle 20° from the horizontal once every 25 seconds. The method consists in measuring the altitude of the spot of light when it is in a vertical plane including the point of observation and the source of light. Simple triangulation then shows the height of the spot of light, or the cloud height, above ground, sea level, or any other base desired.

The point of observation in the example here cited has been the writer's home in Wesley Heights, D. C., having an elevation of 380 feet and being distant 10,520 feet from a point 80 feet directly over the searchlight. By computing the distance $A'\ C'$, shown in the insert of Figure 1, by use of the formula $b = a \cot A'$ where $a = (380-300)$ and $A' = 20°$ (fixed elevation of light), we obtain the value of 220 feet, which, subtracted from 10,520 feet, leaves 10,300 as the value of BFC in the main drawing of Figure 1, where C represents the point of intersection of the beam of light with the horizontal plane of observation, and B, the point of observation.

To solve for d, we have

$$c = \frac{a}{\sin \alpha} \sin \gamma \text{ and } d = c \sin\beta' = \frac{a \sin \gamma \sin \beta'}{\sin \alpha}.$$

Instead of using the angle α, we may use compliments of angles by substituting $\sin \beta$ for $\sin \beta'$ in the numerator and $\sin (20° + \beta)$ for $\sin \alpha$ in the denominator, whereby we use measured angles for computation. Thus the formula becomes

$$d = \frac{a \sin \gamma \sin \beta}{\sin (20° + \beta)} \qquad (1)$$

Examples: When $\beta = 121°$, 90°, and 47°, respectively; or greater than, equal to, and less than a right angle.

$\beta = 121°$

log 10300 (a)	=4. 01284
log sin 20° (γ)	=9. 53405
log sin 121° (β)	=9. 93307
colog sin (20°+121)	= . 20113
Antilog	=3. 68109 d=4798

$\beta = 90°$

log 10300 (a)	=4. 01284
log sin 20° (γ)	=9. 53405
log sin 90° (β)	=0. 00000
colog sin (20°+90)	= . 02701
Antilog	=3. 57390 d'=3749

$\beta = 47°$

log 10300 (a)	$= 4.01284$
log sin 20° (γ)	$= 9.53405$
log sin 47° (β)	$= 9.86413$
colog sin (20°+47°)	$= .03597$
Antilog	$= 3.44699\ d'' = 2799$

Cloud heights with all altitudes of the spot of light between and including 0° and 150° are shown by Figure 2.

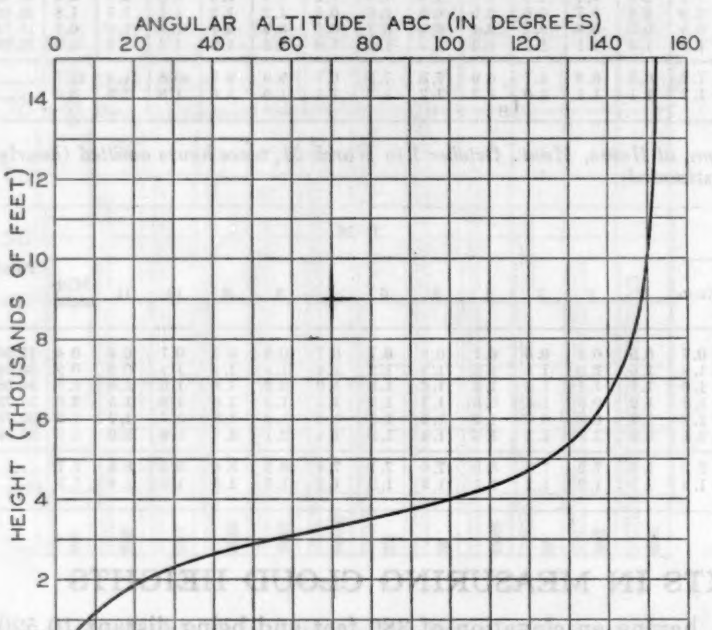


FIGURE 2.—Cloud heights corresponding to various angles of sight, β

It is interesting to note, but perfectly obvious why, that the relation between cloud heights and the distance BC is linear; that is, if the distance BC were 1,030 feet instead of 10,300 feet, all cloud heights shown in Figure 2 would be diminished to one-tenth of their indicated values. Thus, if observations are chiefly desired of cloud heights between 0 and 500 feet, as is usually the case at flying fields, it would be better to have a lesser distance between the light source and the point of observation than that given in the example herewith, but for cloud observations where no additional weight is to be given any particular height, as in the case of regular Weather Bureau cloud observations, it would be preferable to have the observing station so located that a value of 70° for ABC would indicate mean cloud heights. Inspection of Figure 2 shows why this is true, for it will be seen that this is roughly the most nearly horizontal portion of the curve. The heights on curve A rapidly approach infinity when the angle ABC begins to exceed 155°.

Table 1 gives cloud heights corresponding to distances BC of 10,300 feet, 1,000 feet, and 500 feet, respectively, for values of the angle ABC from 1° to 157°, inclusive. These values, however, represent heights above the 380-foot plane and must be added to this latter figure to obtain heights above sea level.

TABLE 1.—*Height of clouds above 380-foot plane corresponding to values of the angular altitude of the spot of light*

Angular altitude, ABC	Value of BFC in feet			Angular altitude, ABC	Value of BFC in feet		
	Height, 10,300 feet	Height, 1,000 feet	Height, 500 feet		Height, 10,300 feet	Height, 1,000 feet	Height, 500 feet
°				°			
0	0	0	0	70	3,310	321	161
1	172	17	8	80	3,523	342	171
2	328	32	16	90	3,749	364	182
5	726	70	35	100	4,006	389	195
10	1,223	119	59	110	4,322	420	210
20	1,875	182	91	120	4,746	461	230
30	2,299	223	112	130	5,397	524	262
40	2,621	254	127	140	6,621	643	321
47	2,799	272	136	150	10,380	1,007	504
50	2,872	279	139	155	17,082	1,658	829
60	3,098	301	154	157	94,985	9,222	4,618

It matters little whether the station is above, below, or on the level with the searchlight. In the first case, the base line is shortened, in the second case it is lengthened, and in the final case no adjustment for height is necessary.

All observations have been made with the alidade of a polariscope, but an altitude finder may readily be fabricated by the use of a brass tube equipped with cross hairs, a protractor, indicating pointer, and standard, at a nominal cost.

A table similar to Table 1, but more comprehensive, should be prepared for use at all stations where regular observations are made as it would soon more than save the amount of time it takes to prepare it.

NOTES, ABSTRACTS, AND REVIEWS

Harry Crawford Frankenfield—an appreciation,[1] *by Dr. Jules Schokalsky, Leningrad, U. S. S. R.*—A post card from my friend Gen. A. W. Greely advised me that an accident had brought to a close the life of Harry Crawford Frankenfield, a man universally loved and esteemed by his many friends. I beg to be permitted to express my personal sorrow in his untimely end and to join with his colleagues of the opposite part of the hemisphere in paying tribute to his memory.

In 1912 while a member of the American Geographical Society's transcontinental excursion, I had the pleasure and opportunity of meeting Frankenfield and discussing with him the many physical problems in which we had a common interest and there was then formed a friendship that endured until the end.

His letters which continued until his death afforded me not only the joy of a kindly scientific support but also revealed in him that quality of spirit possessed only by great souls.

The life and work of Frankenfield, revealing as they did his fine character and sympathetic attitude toward his scientific colleagues assured to his memory their lasting esteem although widely separated in space and time.

Leningrad; November 22, 1929.

MAURY [1]

Two biographies, Life and Letters of Matthew Fontaine Maury, by J. A. Caskie (Richmond, Va.) (press, 1928, 191 p., $3), and Matthew Fontaine Maury: The Pathfinder of the Seas, by C. L. Lewis (the United States Naval Institute, Annapolis, 1928, $6)[2] have recently brought clearly to light the amazing accomplishments

[1] *Cf.* Henry, A. J. Harry Crawford Frankenfield, 1862-1929, Mo. WEA. REV. 57: 254.

[1] *Cf.* Roscoe Nunn's biographical note in the Bulletin, January, 1928, p. 7.

[2] *Cf.* Reviews in *The New York Times*, Mar. 18 and June 17, 1928, respectively.

of a man whose fame could not permanently be lived down by jealous naval officers and disgruntled victors of the Civil War. Maury was not only the pathfinder of the seas, the founder of the United States Naval Academy, Naval Observatory, and Hydrographic Office, but was also the prime mover in laying the first trans-Atlantic cables, and an important factor leading to the founding of our national weather service. For his monumental work on the winds and currents of all the oceans he was recognized the world over as a very great benefactor. His charts shortened voyages by 10 to 20 per cent, saving to British commerce alone many millions of dollars a year. So highly regarded was he that at the outbreak of our Civil War Russia offered him an observatory, all the facilities he wanted, and $30,000 a year. But his sense of duty to Virginia called him from his scientific work to her service in the Civil War.

On Maury's part in the founding of our national weather service, the following passages from Caskie's biography are of interest:

Early in the following year [1858], due to interest created by Maury's lectures and writings, eight cities, including Buffalo, memorialized Congress to "establish a general system of daily telegraphic reports on the wind and weather, for discussion at a central office" (p. 90).

In further substantiation of the claim that Matthew Fontaine Maury was the founder of the National Weather Bureau and Signal Service, the reader's attention is called to the speech of Mr. Vest, of Missouri, December 14, 1880, before the Forty-sixth Congress, third session. During the course of this address, Mr. Vest said:

"The whole signal-service system of this country originated with the Navy, not with the Army. The man who commenced it, in whose brain it first had existence, was M. F. Maury, In 1853 he instigated and brought about, by his own individual exertions, the assembling of a convention of scientists of the world at Brussels, to take into consideration a uniform system of meteorological observations. In 1857 I well recollect that Lieutenant Maury passed through the South and West, delivering lectures at his own individual expense to the people, urging upon them that they urge their members of Congress to establish a signal-service observation system for the Southern and Western States. If that had been done then, sir, millions of dollars would have been saved to the agricultural interests of this country.

"This same man, by his system of research upon the ocean, by shortening the days of transit by means of his charts of the waves and of the winds, saved to the commerce of the world from forty to sixty millions annually, and he sought earnestly, by stirring up people, by writing and lecturing in the North and West and South up to the fall of 1860, and again after the war to within three months of his death, to put the same system into existence within the landed domain of the United States" (p. 108).

In his well-meant tribute to Maury's important part in the establishment of our weather service, Vest appears to have overlooked the contributions of Espy, Loomis, and Joseph Henry to the organization of a meteorological network on the land at the time Maury was so ably coordinating the data from the oceans. Cleveland Abbe, who, in 1869, actually began the forecasting service at Cincinnati that grew into the national weather service, presents the following items on the early history of our weather service:[3]

1847. December 8, Joseph Henry submitted his program of organization and work for the Smithsonian Institution, including first of all "a system of extended meteorological observations for solving the problem of American storms." [The Smithsonian Institution continued after this date a prominent factor in the development of meteorology in the United States.]

1847. Espy and Loomis addressed letters to Prof. Joseph Henry, as Secretary of the Smithsonian Institution, urging the importance of the establishment of meteorological stations and reports for the study of American storms (p. 89).

1854. Prof. Joseph Henry reported that the telegraph companies were furnishing the Smithsonian Institution with daily morning weather reports. He had suggested the custom, which became established, in accordance with which the first message each morning on opening any telegraph office was in answer to the salutation, "Good morning, what is the weather?" Each local operator gave to his division superintendent and the local newspapers a statement of these weather reports, viz, temperature, wind, and weather, and all of them were telegraphed to the Smithsonian Institution, where they were exhibited on a large wall map day after day during the years 1854-1861. These reports were frequently used by Professor Henry to predict or show the possibility of predicting storms and weather, a matter that he frequently urged on the attention of Congress. Espy and Henry were the prime movers in all matters of storm predictions both in this country and in Europe (p. 146).

[3] Chronological outline of the history of meteorology in the United States. MO. WEA. REV., 1909, vol. 37, pp. 87-89, 146-149, 178-180, 252-253.

As was indicated by Mr. Nunn in his biographical sketch of Maury, published in the January, 1928, BULLETIN, p. 7, Maury at his international conference in 1853 urged the establishment of meteorological networks over the lands particularly in the interest of the farmer. So, while Espy and Henry were talking most about storm predictions, Maury was hammering for "meteorology for the farmer" and "weather and crop reports." Their labors ultimately bore fruit, though sooner for the storm warnings than for the agricultural meteorology.—*Charles F. Brooks.*

A long wait for an adequate water supply.—Athens, Greece, celebrated on October 25, 1929, the completion of the Marathon Dam. This dam was erected on a site overlooking the immortal battlefield where in 490 B. C., the Greeks overcame the Persians. It was built to provide Athens with an adequate water supply and it was officially opened by the President of Greece, his cabinet, and other persons in Government circles. A sufficient water supply has always been a problem to the Greek capital as far back as to the time of Solon who, in 594 B. C., enacted laws governing its consumption. Three years ago Ulen & Co. of the United States signed a contract for the construction of the Marathon Dam and a new aqueduct tunnel 8½ miles through the base of Mount Pentelikon. The dam itself is the gravity-section arch type, faced up and down stream with Pentelikon marble of which the classic structures on the Acropolis were built.[1]—*A. J. H.*

Monthly Weather Review Supplement No. 32.—Climatological Data for Southern South America. Mr. Wesley W. Reed contributes under the above title his second statistical report on the climatic conditions of South America. The first report, Supplement No. 31, dealt with northern and western tropical South America. The present contribution presents the statistics with a discussion of the climates of the following countries: Uruguay, Paraguay, Argentine, and Chile, so that the two Supplements, 31 and 32, cover the continent of South America with the exception of Brazil.

The supplement can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. It is priced at 10 cents the copy.—*A. J. H.*

A solar laboratory.—There are several solar observatories, but the only institution in the world calling itself a "solar laboratory" has just been established at the University of Kentucky. In honor of the New York banker who endowed it, the new institution is known as the Percy H. Johnston Solar Laboratory.

Though striking progress has been made in recent years in the knowledge and control of "indoor weather," it appears that one important element has been neglected. We know that certain combinations of air temperature, humidity, and wind are conducive to comfort. The American Society of Heating and Ventilating Engineers has published a number of "comfort charts" for the

[1] Condensed from Hydraulic Engineering, Los Angeles, December, 1929.

guidance of those who design and install ventilating and air-conditioning systems. These charts show the values of the elements above mentioned that, in combination, are most comfortable for persons stripped to the waist, fully clothed, idle, slightly or actively employed, etc. The same society and other agencies have learned much about atmospheric pollution and means of reducing it.

The element that still needs more intelligent regulation is light. The new laboratory is designed especially to study the effects of light on animal and plant life. It is an 8-room building, equipped with the latest types of air-conditioning apparatus. Daylight is admitted through a glass roof, but there are also devices for providing various kinds of artificial light, and the program of investigations is much broader than the title of the laboratory indicates. The director is F. P. Anderson, dean of the College of Engineering at Kentucky University.—*C. F. Talman.*

Empirical factors in weather forecasting.[1]—The Meteorological Office always welcomes friendly and constructive criticism, and therefore it gives me much pleasure to reply to the points raised by Mr. Wilfred Trotter in his letter published in Nature of October 19. Mr. Trotter's main indictment is that modern British forecasts prepared on synoptic charts take too much account of the pressure systems shown on those charts and too little of that general tendency for persistence of weather which sometimes seems to cause fine weather to continue for a long unbroken spell with little regard to the pressure distribution. It would be idle to deny that there may be some truth in this charge, but perhaps I may point out some of the difficulties with which the forecaster is faced. Let us take as an example a case which was fairly common during last summer, when a trough of low pressure over Ireland, stretching down from an Icelandic depression, is moving eastward across the British Isles and probably already giving some rain in Ireland. The question to be answered is, Will this rain spread to the south and southeast of England? The forecaster knows from his experience that in normal circumstances it will generally do so. In the particular type of weather which we are discussing he also knows that the past month or past few months have been abnormally dry. There are these two conflicting elements to be balanced. If he leaves out rain and it comes, he fails in what to many people is the most important factor of his forecast. He decides that he can not take this risk with no better grounds for the omission than the somewhat nebulous one that the summer has so far happened to be abnormally dry. He therefore indicates the probability of some rain; when he comes to the office the next day and reviews the situation, he may wish that he had taken the risk and left out the reference to rain. It is easy to be wise after the event. It must be remembered that, even in a dry summer like the past, there have been days when troughs of low pressure have given rain in the south of England, so that if the forecaster had omitted to mention it on every occasion, he would in some cases have been wrong, and badly wrong.

There is a further point. The Meteorological Office has to forecast for the whole of the British Isles, and it happens that drought in one part of the country coincides with excessive rain in another part. We have been taken to task already this summer for not making enough mention of heavy rains which fell in the West Highlands of Scotland. The forecaster, therefore, who is looking at the whole of the country may not have the dryness of the season impressed upon him quite so strongly as members of the public who see the weather in their own locality only, and from the nature of the case take little account of that in other areas. We have been aware of this tendency to forecast rain more frequently than the event proves to be necessary in dry spells for many years, and if we have failed to benefit by experience, this is due more to the difficulty which I have tried to indicate above than to ignorance of the facts. The cure will be found in more science, not less. When we really understand the workings of the atmosphere and have enough upper air observations to tell us what is happening at the time, we shall know that the particular trough which is approaching can not bring rain; but that time has not arrived yet.

One further criticism is made by Mr. Trotter, and that is with regard to the forecasting of summer thunderstorms, his charge being that too little account is taken of the time of year and that thunderstorms are forecast as confidently in the latter part of August, or even in September, as in the middle of July when the thunderstorm season is at its height. The forecasting of thunderstorms is perhaps the branch into which more scientific method has been introduced than into any other branch of forecasting, and much account is now taken of whether the upper air conditions, as shown by airplane ascents, are stable or unstable. Nevertheless, these observations are not always available when required, and then the older methods of forecasting by pressure distribution and surface temperature have to be used exclusively.

I have not statistics available to show whether Mr. Trotter is right in thinking that the trustworthiness of the forecasts of thunder declines steadily throughout August. The average number of days of thunder at Kew Observatory in August is equal to that in July, and higher than in any other month of the year, though the September figures show a sharp drop. Recent criticisms of our forecasts have suggested that we forecast thunder too often throughout the whole summer, and I believe that this is largely due to the fact that any individual observer is concerned only with the thunder in his immediate vicinity, whereas our forecasts cover a whole district. If a thunderstorm is likely in any part of that district, we do not feel justified in omitting it from the forecast. The number of days in an average summer when thunder is reported at a few isolated places but by no means generally over a district is very considerable.—*J. S. Dines.*

[1] Reprinted from Nature Nov. 9, 1929.

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C. FITZHUGH TALMAN, in Charge of Library

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING NOVEMBER, 1929

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1929, **57:26.**

Table 1 shows that solar radiation intensities averaged below the normal values for November at Madison, Wis., and Lincoln, Nebr., and above the normal at Washington, D. C.

Table 2 shows an excess in the total solar radiation (direct + diffuse) received on a horizontal surface at Chicago, and a deficiency at the other four stations for which normal values have been determined.

Skylight polarization measurements obtained on three days at Washington give a mean of 52 per cent and a maximum of 55 per cent on the 19th. These are considerably below the respective averages for November at Washington. At Madison, measurements obtained on seven days give a mean of 65 per cent and a maximum of 72 per cent on the 15th. These values are close to the corresponding averages for November at Madison.

TABLE 1.—*Solar radiation intensities during November, 1929*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Nov. 2	14.60				1.15						14.10
Nov. 5	3.81	0.73	0.84	1.01	1.23	1.44	1.22	1.05	0.90	0.76	4.17
Nov. 6	5.16				1.20		1.15	0.96	0.78	0.72	5.56
Nov. 11	6.50				1.04		0.96				6.50
Nov. 19	4.95	0.69	0.80	0.95	1.13	1.34					3.99
Nov. 20	5.56						1.26	1.11	0.94	0.86	4.57
Nov. 21	2.87				1.17						4.17
Nov. 26	4.75				1.14						6.02
Nov. 29	1.88			1.04							1.60
Nov. 30	0.94	0.85	1.00	1.12	1.25						0.66
Means		0.76	0.88	1.03	1.16	1.39	1.15	1.04	0.87	0.78	
Departures		+0.01	+0.02	+0.03	−0.02		−0.02	+0.06	+0.04	+0.05	

Madison, Wis.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Nov. 1	4.17	0.79	0.87	1.01							4.57
Nov. 2	4.17	0.85	0.98	1.12	1.34						3.99
Nov. 5	3.63				1.20			0.98			3.99
Nov. 8	4.37							1.03			4.57
Nov. 9	3.45	0.67	0.84	1.00	1.22			0.84			6.50
Nov. 15	3.99	0.99	1.11	1.23	1.41	1.59		1.24			3.81
Nov. 22	0.86	0.88	1.03	1.21	1.40			1.19			0.81
Nov. 26	3.81		0.93	1.06							3.99
Nov. 29	0.71	0.90	1.12	1.26	1.40						0.86
Nov. 30	0.71	0.69	0.84	1.00							1.19
Means		0.84	0.96	1.11	1.33	1.59		1.06			
Departures		−0.04	−0.05	−0.04	+0.02			−0.09			

Lincoln, Nebr.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Nov. 1	3.99			1.06	1.25	1.48					4.57
Nov. 2	3.99	0.85	0.98	1.13	1.31	1.52					4.37
Nov. 4	3.99		1.10	1.23							3.63
Nov. 15	3.81	0.79	0.94	1.10	1.30		1.33	1.13	0.99	0.80	5.36
Nov. 20	3.00				1.41						2.74
Nov. 22	1.02		1.04	1.13							1.88
Means		0.82	1.02	1.13	1.32	1.50	1.33	1.13	0.99	0.80	
Departures		−0.10	−0.02	−0.06	−0.03		−0.03	−0.06	−0.06	−0.13	

[1] Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily radiation: Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Fresno	La Jolla	Average daily departure from normal: Washington	Madison	Lincoln	Chicago	New York
1929	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Oct. 29	158	139	200	72	68	321	322	340	−77	−43	−35	−64	−103
Nov. 5	306	173	206	106	140	254	300	297	+81	+7	−19	−8	−4
Nov. 12	131	121	172	106	67	275	286	310	−61	−16	−26	+7	−57
Nov. 19	162	140	238	169	121	214	239	278	−18	+8	+33	+77	+5
Nov. 26	187	153	194	160	188	230	225	221	+31	+29	+9	+80	+80
Excess or deficiency since first of year on Dec. 2									−5,992	−658	−4,388	−42	−6,496

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Mount Wilson, and Perkins observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups is given for each day in the last column]

Date	Eastern standard civil time		Heliographic: Diff. long.	Longitude	Latitude	Area: Spot	Group	Total area for each day
1929	h.	m.	°	°	°			
Nov. 1 (Naval Observatory).	11	35	−41.5	174.8	+3.5	9		
			−31.0	185.3	+16.0		247	
			+22.0	238.3	+10.0		571	
			+48.5	264.8	+14.0		231	1,058
Nov. 2 (Naval Observatory).	10	36	−36.0	167.6	−11.5	6		
			−16.0	187.6	+13.5		525	
			+8.5	212.1	−16.0	3		
			+35.0	238.6	+9.5		586	
			+62.0	265.6	+13.0		185	1,305
Nov. 3 (Perkins Observatory).	10	42	−76.5	113.7	−10.0	217		
			−10.1	180.1	+12.1		124	
			−2.4	187.8	+13.8		837	
			+4.6	194.8	+14.0		806	
			+49.7	239.9	+9.9		589	
			+75.8	266.0	+11.8	62		2,635
Nov. 4 (Naval Observatory).	13	33	−64.0	111.6	−11.5	494		
			−17.5	158.1	+15.0		25	
			+2.0	177.6	−21.0	6		
			+13.5	189.1	+14.0		926	
			+28.0	203.6	−11.5	6		
			+35.0	210.6	−15.5	6		
			+63.0	238.6	+9.0		448	1,911
Nov. 5 (Naval Observatory).	10	55	−53.0	110.9	−11.5	463		
			−43.0	120.9	+4.5	3		
			−5.5	158.4	+15.0		15	
			+24.5	188.4	+14.5		1,096	
			+41.5	205.4	−11.0		15	
			+75.5	239.4	+9.0		340	1,932
Nov. 6 (Naval Observatory).	11	0	−80.5	70.1	−12.5	201		
			−39.5	111.1	−11.5	571		
			−26.5	124.1	+3.5	6		
			+9.0	159.6	+5.0	6		
			+10.0	160.6	+14.5	9		
			+39.0	189.6	+15.0		1,127	1,920
Nov. 7 (Naval Observatory).	11	18	−69.0	68.3	−13.5		340	
			−26.5	110.8	−12.0	463		
			+5.0	142.3	−24.5		15	
			+24.5	161.8	+6.0	15		
			+52.5	189.8	+14.5		1,157	1,990
Nov. 8 (Perkins Observatory).	13	25	−49.6	73.2	−11.8	403		
			−10.3	112.5	−10.9	1,767		
			+62.8	185.6	+15.2		589	
			+74.6	197.4	+14.3	279		3,038
1929								
Nov. 9 (Naval Observatory).	10	54	−80.5	30.7	−7.0	22		
			−79.0	32.2	+6.5	216		
			−65.0	46.2	−10.5	93		
			−40.0	71.2	−13.0		262	
			+0.5	111.7	−11.5		509	
			+54.5	165.7	+5.5		15	
			+78.5	189.7	+15.5		1,111	2,228
Nov. 10 (Naval Observatory).	10	44	−68.0	30.1	+7.0		370	
			−66.5	31.6	−6.5	31		
			−51.0	47.1	−10.5	77		
			−49.0	49.1	+16.5	6		
			−26.5	71.6	−12.0	247		
			+13.5	111.6	−11.5		463	
			+43.0	141.1	+5.5		9	
			+63.0	161.1	+13.0		18	
			+85.5	183.6	+15.5	370		1,591
Nov. 11 (Naval Observatory).	11	7	−56.5	28.2	+7.0		432	
			−54.0	30.7	−7.0	31		
			−38.0	46.7	−11.0	62		
			−13.0	71.7	−12.0	247		
			+27.0	111.7	−11.5		556	
			+59.5	144.2	+5.0	18		1,346
Nov. 12 (Naval Observatory).	12	39	−53.0	17.6	−7.0	12		
			−41.0	29.6	−5.5		108	
			−40.5	30.1	+7.0		401	
			−23.5	47.1	−11.5		77	
			+1.0	71.6	−11.5	247		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929—Contiuued	h. m	°	°	°			
Nov. 12 (Naval Observatory).	12 39	+41.0	111.6	−11.5		494	
		+74.0	144.6	+5.5		62	1,401
Nov. 13 (Mount Wilson)	13 20	−37.0	20.1	−5.0		131	
		−28.0	29.1	−5.0		27	
		−25.0	32.1	+7.0		256.	
		−20.0	37.1	+14.0	55		
		−9.0	48.1	−9.0	28		
		+15.0	72.1	−10.0	224		
		+55.0	112.1	−11.0		447	1,168
Nov. 14 (Yerkes)	16 34	−23.7	18.4	−6.3	155		
		−18.3	23.8	+8.2	76		
		−18.0	24.1	−6.3		175	
		−5.9	36.2	+5.4	432		
		−1.3	40.8	+11.8		97	
		+5.8	47.9	−10.3	78		
		+29.9	72.0	−10.6	446		
		+69.3	111.4	−13.0		569	2,028
Nov. 15 (Yerkes)	11 30	−11.6	20.1	−5.6		124	
		−9.8	21.9	−6.1	21		
		−8.1	23.6	−6.1		52	
		−7.3	24.4	+8.3	17		
		−6.8	24.9	−6.1	92		
		+2.5	34.2	+7.4	11		
		+7.6	39.3	+5.4	411		
		+10.7	42.4	+11.3		79	
		+16.3	48.0	−10.5	90		
		+39.9	71.6	−10.6	413		
		+78.8	110.5	−11.6		580	1,890
Nov. 16 (Naval Observatory).	10 44	−72.5	306.5	+9.0		247	
		+3.5	22.5	−7.0		278	
		+18.0	37.0	+4.5	247		
		+23.5	42.5	+11.0		108	
		+29.5	48.5	−11.0	31		
		+52.5	71.5	−11.5	185		1,096
Nov. 17 (Mount Wilson)	12 45	−59.0	305.7	+8.0		138	
		+20.0	24.7	−6.0		353	
		+32.0	36.7	+5.0		326	
		+38.0	42.7	+11.0		38	
		+45.0	49.7	−11.0	24		
		+69.0	73.7	−10.0		219	1,098
Nov. 18 (Naval Observatory).	11 14	−44.5	307.8	+10.0		262	
		+31.5	23.8	−6.5		324	
		+44.5	36.8	+4.5	216		
		+50.0	42.3	+10.5		22	
		+56.0	48.3	−11.0	31		
		+81.0	73.3	−11.5	170		1,025
Nov. 19 (Naval Observatory).	11 12	−30.5	308.7	+10.0		201	
		+44.5	23.7	−6.5		278	
		+57.5	36.7	+4.5	231		
		+68.5	47.7	−11.5	25		735
Nov. 20 (Naval Observatory).	11 54	−47.0	278.6	−14.5		46	
		−17.0	308.6	+10.0		262	
		+61.0	26.6	−7.0		231	
		+71.5	37.1	+4.0	201		740
Nov. 21 (Naval Observatory).	11 1	−84.5	228.4	+12.0		648	
		−72.0	240.9	+8.5	123		
		−4.5	308.4	+10.0		247	
		+73.5	26.4	−7.5	201		
		+85.0	37.9	+4.0	216		1,435
Nov. 22 (Perkins Observatory).	15 11	−70.6	226.5	+11.8	248		
		−65.2	231.9	+13.6	341		
		−57.5	239.6	+9.2	93		
		+7.6	304.7	+11.0		124	
		+14.7	311.8	+10.9	217		1,023
Nov. 23 (Mount Wilson)	13 20	−80.0	205.3	+12.0		102	
		−70.0	215.3	−20.0		299	
		−54.0	231.3	+14.0		803	
		−45.0	240.3	+10.0	102		
		+25.0	310.3	+10.0		125	1,431
Nov. 24 (Mount Wilson)	13 40	−75.0	196.9	+18.0		981	
		−66.0	205.9	+11.0		132	
		−60.0	211.9	−19.0		273	
		−41.0	230.9	+13.0		741	
		−31.0	240.9	+10.0	74		
		+42.0	313.9	+9.0		140	2,341
Nov. 25 (Naval Observatory)	11 45	−80.0	179.8	+12.0	154		
		−80.0	179.8	+18.5	31		
		−71.5	188.3	+15.5	31		
1929—Continued	h. m.	°	°	°			
Nov. 25 (Naval Observatory).	11 45	−62.0	197.8	+15.5	926		
		−55.0	204.8	+10.0		340	
		−44.0	215.8	−21.5		247	
		−29.5	230.3	+12.5		664	
		−20.0	239.8	+8.5	62		
		+53.5	313.3	+10.0	108		2,563
Nov. 26 (Naval Observatory).	11 2	−66.5	180.5	+16.0		386	
		−50.0	197.0	+16.5	802		
		−41.0	206.0	+11.0		231	
		−30.5	216.5	−21.0		185	
		−17.0	230.0	+12.5		586	
		−13.5	233.5	+5.5	6		
		−7.0	240.0	+8.5	34		
		+67.5	314.5	+10.5	108		2,338
Nov. 27 (Naval Observatory).	10 46	−82.5	151.5	+6.5	139		
		−71.0	163.0	+17.0		170	
		−54.5	179.5	+15.5		741	
		−36.5	197.5	+16.0	802		
		−29.5	204.5	+11.0		278	
		−18.0	216.0	−21.0		185	
		−4.0	230.0	+12.0		556	
		+5.5	239.5	+9.0	34		
		+16.5	250.5	+10.5		31	
		+79.5	313.5	+10.5	108		3,044
Nov. 28 (Naval Observatory).	11 8	−68.0	152.6	+5.5	123		
		−57.5	163.1	+17.0		355	
		−40.5	180.1	+15.0		648	
		−23.0	197.6	+16.0	741		
		−15.0	205.6	+10.5		262	
		−4.5	216.1	−21.5		216	
		+10.0	230.6	+11.5		404	
		+20.0	240.6	+8.5		62	
		+31.0	251.6	+12.0	15		2,916
Nov. 29 (Naval Observatory).	11 6	−54.5	152.9	+6.0	123		
		−44.0	163.4	+17.0		340	
		−27.0	180.4	+15.0		1,034	
		−9.5	197.9	+16.0	710		
		−0.5	206.9	+10.0		324	
		+6.0	213.4	−22.0		278	
		+23.0	230.4	+11.5		401	
		+31.5	238.9	+8.5		46	3,256
Nov. 30 (Noval Observatory).	11 9	−40.5	153.7	+6.5	108		
		−30.0	164.2	+17.0		355	
		−13.0	181.2	+15.5		1,296	
		+4.0	198.2	+16.5	710		
		+11.5	205.7	+11.0		324	
		+21.5	215.7	−21.5		247	
		+36.5	230.7	+11.5		540	
		+47.0	241.2	+7.5		40	3,620
Mean daily area for November.							1,870

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR NOVEMBER, 1929 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

November, 1929	Relative numbers	November, 1929	Relative numbers	November, 1929	Relative numbers
1		11	71	21	a d 44
2	81	12	a 68	22	41
3	b d	13	Ec 82	23	d 51
4	92	14	a	24	d 60
5	129	15	a 93	25	81
6	d 100	16	a d 65	26	90
7	80	17	67	27	b 119
8	91	18	67	28	a 127
9	d b 80	19	49	29	b 146
10	94	20	44	30	b

Mean, 26 days=81.2.

[1] Dependent alone on observations at Zurich and its station at Arosa.
a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity; E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Endtrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures for November were considerably below normal at all stations except Due West. (Table 1.) Departures decreased, in general, with altitude except at Royal Center where the means continued relatively low. The temperatures shown for the naval air stations (Table 2) are found to be in good agreement with those of the kite stations, when geographical differences are considered.

Mean free-air relative humidities were mostly above normal and those of vapor pressure below, except as, might be expected at Due West where positive temperature departures occurred. In this connection it is of interest to note that the monthly precipitation at Due West exceeded all previous records for November since the establishment of the station in 1921.

The resultant wind movement at 1,000 m. (m. s. l.) was predominantly west over the country east of the Rockies, except over Florida, where it was south over Jacksonville, and east over Key West. Resultant velocities at this level decreased generally with latitude and ranged from 9 m. p. s. over the Northern States to 1 m. p. s. over the Gulf region. At 3,000 m. a pronounced westerly component prevailed at all stations except over the Pacific coast and Key West, where the directions were northerly and southerly, respectively. The highest resultant velocities at this level occurred over the eastern part of the country where they reached 16 m. p. s.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during November, 1929*

TEMPERATURE (° C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	5.3	−4.4	11.7	+0.6	−3.1	−0.8	7.5	−5.7	0.1	−4.6
500	4.7	−3.9	10.2	+0.2	−3.3	−1.0	6.6	−5.8	−1.5	−4.6
1,000	2.8	−4.6	8.3	+0.1	−3.8	−1.9	4.8	−6.4	−3.1	−4.7
1,500	1.3	−5.1	6.9	+0.3	−5.1	−2.9	4.0	−5.6	−4.7	−5.0
2,000	−0.1	−4.8	5.5	+0.5	−7.0	−3.2	3.6	−4.1	−6.5	−5.0
2,500	−1.4	−3.9	3.3	+0.1	−9.0	−3.0	3.3	−2.3	−7.8	−4.4
3,000	−3.1	−3.2	1.4	+0.4	−11.3	−2.7			−10.4	−4.7
4,000	−7.4	−2.6			−15.7	−1.4			−16.5	−6.0
5,000	−12.9	−2.6			−21.7	−2.1				

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during November, 1929*—Continued

RELATIVE HUMIDITY (%)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	73	+6	74	+4	75	−3	75	+1	82	+9
500	69	+5	67	+2	74	−2	66	−1	80	+8
1,000	64	+5	62	0	65	0	63	+4	71	+4
1,500	60	+8	56	−1	59	+1	61	+9	61	+2
2,000	60	+13	58	+6	56	+1	68	+22	55	+1
2,500	57	+14	50	+6	57	+3	73	+33	49	−1
3,000	51	+9	41	+1	56	+2			50	+1
4,000	49	+14			51	−5			55	+10
5,000	49	+16			59	+9				

VAPOR PRESSURE (*mb.*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	6.57	−1.65	11.47	+1.72	3.82	−0.42	7.97	−4.06	5.53	−1.07
500	6.02	−1.38	9.84	+1.27	3.72	−0.44	6.44	−4.09	4.83	−1.01
1,000	4.83	−1.40	8.17	+0.94	2.89	−0.67	5.57	−2.94	3.94	−0.88
1,500	4.06	−0.99	6.49	+0.75	2.44	−0.64	5.24	−2.35	3.00	−0.81
2,000	3.58	−0.34	5.60	+1.16	1.97	−0.64	5.95	+0.04	2.55	−0.49
2,500	3.05	0.00	3.65	+0.55	1.67	−0.54	6.18	+1.36	2.21	−0.26
3,000	2.23	−0.23	1.81	−0.45	1.34	−0.47			2.03	−0.13
4,000	1.85	+0.51			0.91	−0.28			1.58	+0.32
5,000	1.58	+0.76			0.63	−0.08				

TABLE 2.—*Free-air data determined at Naval Air Stations during November, 1929*

Altitude (meters) m. s. l.	Temperature (° C.)			Relative humidity (%)		
	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	13.6	19.8	5.5	87	44	73
500	13.2	17.7	4.4	73	35	67
1,000	12.6	16.9	2.9	70	23	62
2,000	11.2	12.5	−0.7	55	14	52
3,000	7.3		−3.1	43		36
4,000			−8.9			67

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during November, 1929*

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,868 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles Calif. (40 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	N 28 W	0.7	S 20 W	2.7	N 73 W	6.8	N 13 E	0.6	N 62 W	3.2	N	2.4	S 68 W	3.1	N 15 W	0.6	N 66 E	2.6	N 53 W	2.7
500	N 88 W	2.2	S 40 W	6.2			S 58 W	0.7	N 65 W	4.1	N 31 E	3.4			S 28 E	1.0	N 84 E	6.6	N 77 E	0.2
1,000	N 89 W	4.3	S 72 W	7.5			N 78 W	3.7	N 52 W	7.1	N 17 W	2.1	S 87 N	7.1	S 12 W	1.7	S 73 E	5.5	N 87 E	0.5
1,500	N 72 W	5.1	S 85 W	9.6			S 84 W	8.4	N 56 W	9.0	N 87 W	3.9	N 59 W	10.1	S 52 W	3.0	S 59 E	4.5	N 48 E	2.2
2,000	N 73 W	7.5	N 85 W	11.4	N 68 W	9.4	S 87 W	11.5	N 62 W	10.0	N 83 W	7.5	N 54 W	10.7	S 69 W	4.0	S 64 E	3.3	N 44 E	3.8
2,500	N 78 W	10.6	N 89 W	12.6	N 50 W	11.4	N 89 W	14.1	N 56 W	11.4	S 85 W	9.5	N 60 W	11.7	S 68 W	5.0	S 66 E	2.3	N 31 E	5.6
3,000	N 80 W	13.2	W	13.0	N 42 W	10.2	S 89 W	14.5	N 59 W	11.1	S 72 W	10.2	N 53 W	11.8	S 65 W	3.3	S	0.6	N 8 E	5.7
4,000	N 89 W	16.2			N 46 W	9.4	S 84 W	19.5							S 71 W	4.1	S 62 W	3.1	N 4 W	2.1
5,000							S 79 W	16.3							N 81 W	8.1	S 69 W	4.0		

Altitude m. s. l.	Medford, Oreg. (446 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (313 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,280 meters)		San Francisco, Calif. (60 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (67 meters)		Washington, D. C. (34 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	S 32 W	0.2	N 14 E	0.8	N 42 E	1.6	N 65 W	1.3	S 69 W	2.1	S 40 E	1.4	N 75 E	1.1	S 24 W	1.0	N 46 E	0.9	N 81 W	1.2
500	S 29 W	0.1	N 11 W	1.6	N 47 E	3.2	N 58 W	4.0	N 86 W	5.6			N 7 E	3.1	S 64 W	4.0	N 42 E	1.3	S 87 W	7.4
1,000	S 66 E	1.6	N 26 W	4.8	N 50 W	1.2	N 54 W	6.5	N 80 W	9.0			N 15 E	5.9	S 80 W	7.2	N 39 E	0.7	N 75 W	8.4
1,500	S 63 E	1.8	N 68 W	5.9	N 80 W	3.8	N 57 W	7.5	N 80 W	10.3	S 16 E	2.0	N 10 E	5.4	S 86 W	7.3	N 5 W	2.2	N 88 W	12.6
2,000	N 34 E	2.2	N 83 W	8.6	S 83 W	4.9	N 67 W	8.2	N 82 W	12.5	S 44 W	1.2	N 3 E	4.7	N 77 W	9.1	N 2 E	3.1	N 86 W	16.0
2,500	N 11 E	5.3	S 81 W	9.9	S 89 W	7.6	N 73 W	7.9	S 87 W	12.0	N 55 W	3.3	N 5 E	4.8	N 25 W	8.3	N 12 W	4.5	S 88 W	15.8
3,000	N 4 E	6.8					N 65 W	8.3	N 72 W	13.7	N 28 W	7.8	N 2 E	6.1					S 80 W	16.2
4,000	N 14 W	6.6					N 61 W	7.1			N 21 W	11.2	N 11 E	5.8						
5,000											N 23 W	15.9								

TABLE 4.—*Observations by means of kites, captive and limited-height sounding balloons, during November, 1929*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters) m. s. l., reached during month	2,836	2,264	3,389	1,940	2,539
Maximum altitude (meters) m. s. l., reached and date	[1] 6,131	[2] 3,616	[3] 5,188	[4] 2,749	[5] 4,024
Number of flights made	27	29	33	16	24
Number of days on which flights were made	26	27	30	16	24

[1] 22d. [2] 14th. [3] 15th. [4] 6th. [5] 19th.

In addition to the above there are approximately 120 pilot-balloon observations made daily at 50 Weather Bureau Stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By P. C. DAY

GENERAL SUMMARY

The outstanding features of the weather during November were the marked cold over the districts from the Mississippi River eastward to the Atlantic coast at the end of the month, and the continued drought over the area from the Rocky Mountains to the Pacific coast, particularly in the more westerly portions where precipitation had been deficient for many months, and the season up to the end of November had been the driest ever known. This drought continued into December, but was partly broken in the first decade of that month and rather fully relieved by the middle of the month.

PRESSURE AND WINDS

At the beginning of the month an extensive area of precipitation had overspread much of the country from the Great Plains eastward, but precipitation was generally light save in a few small areas. By the morning of the 2d precipitation had largely ceased save over a narrow area extending from southern Texas northeastward to New England, continuing over practically the same area, but moving slightly eastward during the following two days, the falls becoming comparatively heavy locally during the 4th along or near the coast from central Georgia northeastward to the Chesapeake Bay region, the rain area practically disappearing beyond New England by the morning of the 5th.

At the morning observation of the 6th, low pressure had advanced into the central Plateau without much precipitation, and during the following 24 hours it moved to central New Mexico, attended by snows in the middle mountain region, and some rains had fallen in Texas and near-by areas. The pressure in that locality continued to fall, and, by the morning of the 8th, rain or snow had overspread a considerable portion of the southern Plains, and had extended into the west Gulf sections, continuing on the 9th over much of the same territory, the falls becoming locally heavy in portions of Texas and near-by areas. This rain area continued into the 10th, extending northward to the Great Plains and to near the western upper Lake region, with local heavy rains continuing in the coast districts of Texas. This area did not develop much strength and passed to the northward of the Great Lakes by the morning of the 11th, the precipitation extending eastward and southward into the lower Lake region, Ohio Valley, and Middle Gulf States, the area finally passing northeastward into the lower St. Lawrence Valley by the following morning.

Immediately following this, cyclonic conditions had moved from the Southwest but without material precipitation until the morning of the 12th, when rain had set in over a rather broad area from central Texas to the southern Appalachians and light snows were falling over the Middle Plains. By the following morning precipitation had become rather general from the eastern Plains to the Great Lakes and Appalachian Mountains. A second low-pressure area from the central Gulf during the 13th reinforced the depression, and by the morning of the 14th the center of the disturbance had moved to the lower Ohio Valley, while heavy rains had occurred over large portions of the Middle Gulf and Ohio Valley States, with the rain area extending northeastward to New England. Rain continued into the 15th over most eastern districts, the falls continuing heavy in Alabama and portions of Mississippi and other nearby States, though clearing in many districts by the morning of the 16th. However, rains continued over much of the Southeast, extending into the middle Appalachian region during the 17th, and into nearly all Atlantic coast and Great Lakes districts during the following two days.

Local light snows occurred in the northern Plains during the 20th to 22d, and rains had overspread much of the Gulf region by the morning of the last-named date, changing to snow in the southern drainage basin of the Ohio River, which during the 23d extended eastward to the south and middle Atlantic coasts, the precipitation becoming heavy in most eastern sections of the rain area.

Some light precipitation, mostly snow, occurred over northern districts during the period 23d to 26th, and rather general precipitation occurred over the Gulf districts on the last-named date; also snow or rain continued from that time to the end of the month at many scattered points in both the northern and central districts east of the Rocky Mountains.

Sea-level pressures were well above the normal over all central and western districts, anticyclonic conditions existing to a marked extent in the far Northwest, and thence southeasterly to the Great Plains and west Gulf States.

Cyclonic conditions existed over the eastern third of the country, and much cloudy, rainy weather persisted in that region.

Compared with the preceding October, pressure was higher, as is usually the case, in all parts of the country, save over a small area from the Great Lakes eastward to near the Atlantic coast, where the average sea-level pressures were slightly less than in October.

As is frequently the case in late autumn, few severe storms occurred in any part of the country, and damage or loss by winds was at the minimum. Such few storms as were reported are summarized in the usual table at the end of this section.

TEMPERATURE

The first two decades were mainly free from extreme ranges in temperature, though minor changes were frequent, but no severe winter weather persisted over any extended area. However, beginning with the third decade winter weather set in over most districts from the Rocky Mountains eastward, and continued in most of that area with more or less severity throughout the remainder of the month.

The week that ended November 26 was cold over nearly all parts of the country and decidedly so over the interior districts, where the weekly averages ranged up to as much as 15° below normal. A few sections during this week had averages slightly above normal, notably southern Florida and the coast districts of central California.

The last three days of the month had temperatures well below the normal over many parts of the country from the Rocky Mountains eastward, severe cold extending into the central valleys and southern districts, with temperatures below freezing on the morning of November 30 over practically all the Gulf coast region, and into the northern districts of Florida. The minimum temperatures during this period were the lowest of record for November over a large area from the Ohio Valley eastward to the Atlantic coast, and even in the far South many stations reported this period as the second coldest of record for November in the last 50 years or more.

In the far West this period was moderately warm and no severe winter weather was reported from that section during the month.

For the month as a whole temperatures were below normal from the Great Lakes and Ohio Valley southward to the Gulf and westward to the Rocky Mountain region and portions of the north Pacific coast, save for a small area in North Dakota and eastern Montana, and thence northward into Canada. Over many portions of the central valleys the month was decidedly cold, particularly in the southern Plains and West Gulf districts, where a number of stations reported mean temperatures for the month as the lowest of record for November.

The highest temperatures of the month were reported during the first few days in the far western districts and in the eastern districts from the lower Mississippi Valley northeastward to the Great Lakes. In the central valleys the highest temperatures occurred very generally about the middle of the month. The highest reading, 98°, occurred on the 3d, and was reported from a point in the interior of southern California.

Minimum temperatures occurred mainly during the closing days of the month, particularly on the 30th in the more eastern districts, though in the Great Plains and mountain regions they occurred about the 21st and 22d, and in a few far Western States they occurred earlier in the month. Minimum temperatures of 32° or lower occurred at some point in each State, and temperatures below zero were reported as far south as Texas and thence northeast to New England. The lowest reported, −38°, occurred in the mountains of Wyoming.

PRECIPITATION

The monthly amounts of precipitation were heavy and above normal over a general area extending from eastern Texas northeastward to the lower Lakes and thence eastward to near the Atlantic coast where the falls were frequently twice or even three or more times the normal. To the eastward of this area along or near the south Atlantic coast and over Florida, the monthly amounts were much less, not exceeding 25 per cent of the usual falls in portions of Florida. A second area of precipitation in excess of the normal, though here the amounts were far less than in the area first referred to, the monthly amounts ranging up to twice and even three times the usual falls, covered the middle and southern Rocky Mountains and portions of near-by States. From central Texas northeastward to the upper Lakes, the precipitation was mainly less than the normal and over the entire northern border there was usually less than the normal precipitation, this being particularly true over the districts west of the Rocky Mountains and all other far

western sections, where there were extensive areas with little or no rain or snow during the entire month.

In much of this western area the precipitation was the least of record for November since observations began, or at most it was the second November of no precipitation in more than 50 years. At a few places in the northern Plateau region, November is usually the month of greatest precipitation, but in the present November these places were frequently entirely without precipitation.

As a result of this deficiency in precipitation the water supply is greatly depleted, rivers are at low stages, springs and wells have gone dry in many instances, the fire hazard has been greatly increased, and forest fires have been controlled only with difficulty; while vegetation has been greatly retarded, winter pasturage is largely exhausted, and much stock feeding has been necessary.

SNOWFALL

The distribution of snow partook largely of that of a winter month from the Rocky Mountains eastward, the falls being widely distributed and the amounts in localities the greatest of record for November.

From the Great Plains eastward to the Atlantic coast there was more or less snow in all save the more southern districts, the falls being unusually heavy so early in the season over a considerable area from northwest Texas to the southern Appalachian Mountains, where falls near the end of the month ranged from 6 to 8 inches or more.

Farther north the amounts usually were less, until over North Dakota and some near-by areas where some snow that fell late in October remained unmelted at the end of that month, and, with amounts that occurred during November, formed a covering of snow that remained unmelted throughout the month. The total falls were comparatively heavy in the northern parts of the upper Lake region and locally in northern New York, but in New England the amounts for the month were mainly moderate. In the Rocky Mountains and over their eastern foothills good depths of snow were reported generally, but there was little in much of the Plateau region and practically none in the Sierra Nevada and Cascade ranges, none being reported from the highest peaks in California, a condition rarely experienced in that State.

RELATIVE HUMIDITY

Over much of the country from the Rocky Mountains eastward the percentages of relative humidity were above the monthly normals, save for small areas from the upper Lakes northeastward. In portions of the Rocky Mountains the departures from the normal were large, ranging up to 15 to 20 per cent. On the other hand, west of the Rocky Mountains, the humidities as represented by the departures from normal were mainly far less than normal, as would also be indicated by the great lack of precipitation in that area. This general dryness was augmented by the large percentage of sunshine in that region which averaged nearly 100 per cent of the possible at many places in California and other portions of the Southwest.

SEVERE LOCAL STORMS, NOVEMBER, 1929

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the chief of bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Crossroads, N. Mex	8					Heavy hail	Considerable damage to range over 50 square miles.	Official, U. S. Weather Bureau.
Portland, Me., and vicinity.	17–19					Ice	Public utilities, especially telephone and telegraph companies, suffer heavy loss; many shade trees stripped; factories closed.	Do.
Iowa (parts of)	27					Wind and sleet	Plate-glass windows broken; many small buildings in rural sections wrecked.	Do.
Des Moines, Iowa	29					Wind	Small out buildings demolished; plate-glass windows broken.	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES

There were overflows in November, 1929, in the South Atlantic States and the Ohio River basin, but they were of minor importance, except in the Tennessee River and in that part of the east Gulf drainage area lying between the Apalachicola and the Mississippi Rivers.

Excessive rains fell from the 10th to the 17th in northwestern Georgia, Alabama, Mississippi, and the Louisiana Parishes east of the Mississippi River. There were numerous falls amounting to 10 inches in eight days, and one station, Helena, Ala., had 15.97 inches. The rivers began to rise rapidly on the 12th and 13th, flood stages were reached about the 15th, and in the lower reaches the overflow continued until the 25th. The water levels were not particularly high, but the inconvenience and damage were relatively great on account of the general overflow of all the minor streams, and the long continued flood in the larger rivers. The following tabular statement is a summary of the statistics of loss and damage. The information, of course, is not complete, but represents the best that is available.

	Alabama River system	Tombigbee-Black Warrior Rivers	Pascagoula and Pearl Rivers	Tennessee River	Total
Buildings, highways, bridges, etc	$27,450	$89,000	$36,000	$2,200	$154,650
Matured crops	71,100	24,200	3,600	31,000	129,900
Prospective crops	[1] 5,250	[2] 2,700			7,950
Movable property, including livestock	850	80,000	2,500		83,350
Suspension of business, including wages	15,300	103,000	48,200	14,500	181,000
Total	119,950	298,900	90,300	47,700	556,850

[1] 1,100 acres. [2] 1,200 acres.

The warnings issued were timely and adequate. The savings effected through their use have been reported to have been $127,000 on the Alabama River system, $229,000 in the valleys of the Black Warrior and the Tombigbee, $26,000 in the Pascagoula and Pearl Valleys, and $8,500 in the Tennessee Valley, a total of $390,500.

Flood stage and crest data are given in the following table:

[All dates in November except as otherwise specified]

River and station	Flood stage	Above flood stages—dates: From—	To—	Crest: Stage	Date
ATLANTIC DRAINAGE	*Feet*			*Feet*	
James: Columbia, Va	18	20	20	20.7	20
Tar:					
Tarboro, N. C	18	9	9	18.1	9
Greenville, N. C	14	[1]	1	18.8	Oct. 29
		9	11	14.5	10
Neuse: Smithfield, N. C	14	5	8	17.0	6
Cape Fear: Elizabethtown, N. C	22	6	7	24.1	6
Peedee: Mars Bluff, S. C	17	8	10	17.9	9
		30	[2]	17.0	30
Santee:					
Rimini, S. C	12	[1]	5	31.8	Oct. 6
		7	[2]	14.0	9, 10
Ferguson, S. C	12	[1]	[2]	21.0	Oct. 7
Saluda:					
Pelzer, S. C	7	18	18	7.0	18
Chappells, S. C	14	19	20	14.8	20
EAST GULF DRAINAGE					
Conecuh: Brewton, Ala	13	17	26	16.3	22
Alabama:					
Montgomery, Ala	35	15	25	47.9	19
Selma, Ala	35	15	28	50.7	20, 21
Coosa:					
Gadsden, Ala	22	15	25	26.0	18, 19
Lock No. 4, Lincoln, Ala	17	14	26	22.6	16
Wetumpka, Ala	45	17	20	48.7	18
Etowah: Canton, Ga	11	15	15	11.1	15
Oostanaula: Resaca, Ga	25	16	20	28.5	17, 18
Cahaba: Centerville, Ala	25	12	17	35.0	15
Tombigbee: Lock No. 4, Demopolis, Ala	39	14	[2]	63.7	21, 22
Black Warrior: Lock No. 10, Tuscaloosa, Ala	46	12	20	65.1	15
Chickasawhay:					
Enterprise, Miss	21	15	17	25.0	16
Shubuta, Miss	27	17	21	31.7	19
Leaf: Hattiesburg, Miss	19	16	18	22.0	16
Pearl:					
Jackson, Miss	20	17	[2]	25.8	23–26
Monticello, Miss	18	14	18	20.4	14
Columbia, Miss	18	15	21	23.5	16
Bogue Chitto: Franklinton, La	16	15	16	17.3	16
West Pearl: Pearl River, La	13	7	13	15.2	7
		16	[2]	16.3	18
MISSISSIPPI DRAINAGE					
Monongahela: Lock No. 7, Greensboro, Pa	30	18	18	30.2	18
Ohio: Dam No. 25, near Point Pleasant, W. Va	40	20	20	40.0	20
Hocking: Athens, Ohio	17	19	19	17.25	19
Tennessee:					
Widows Bar Dam, Ala	26	16	21	----	----
Guntersville, Ala	31	18	19	31.0	18, 19
Florence, Ala	18	16	22	19.7	19
Riverton, Ala	33	16	24	39.0	20
Elk: Fayetteville, Tenn	14	3	3	15.0	3
		15	18	17.4	15
WEST GULF DRAINAGE					
Colorado: Columbus, Tex	28	9	9	30.0	9

[1] Continued from last month. [2] Continued at end of month.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, NOVEMBER, 1929

By J. B. KINCER

General summary.—Early in the first decade weather conditions were generally unfavorable for outside operations in most places east of the Rocky Mountains and these detrimental conditions continued during the latter part in the South, although in the Southeast seasonal work made fairly good advance. Rain was needed in the Florida Peninsula, but there was a generally ample supply of soil moisture nearly everywhere east of the Rockies; west of the mountains droughty conditions continued. Cool weather brought frosts nearly to the southern part of the country, but with no material damage; there was some harm to livestock in the Northwest from the severe weather.

During the second decade frequent rains and muddy fields made conditions generally unfavorable for farm work in the central valleys and in much of the South, but rain was still needed in the extreme Southeast, especially on the uplands of Florida. There was some damage to outstanding crops from overflowed lowlands in parts of the Southeast. In the northern area conditions were more favorable for outside operations, with the snow cover decreased and free ranging of livestock permitted. Droughty conditions continued west of the Rocky Mountains.

The unseasonably cold weather during the last decade, attended by frequent rains in the Southeast and snows in the northern portions of the country, caused a general suspension of outdoor work. Freezing weather extended well into the southern portions of the country in the Southwest, with some damage to tender truck in Texas. At the close of the month there was a general, fairly good snow cover in most of the northern half of the country, affording protection to winter grains and meadows. Droughty conditions still prevailed west of the Rocky Mountains, with snow deficient on desert ranges.

Small grains.—During the first decade winter wheat continued to make good advance in the main producing sections, with generally ample soil moisture; some western parts of the belt reported the best moisture conditions in many years. Snows in parts of the Northwest were especially favorable for winter grains, but in the Pacific Northwest the continued dry conditions were very detrimental, delaying seeding, plowing, and germination.

East of the Rockies, satisfactory condition of winter wheat continued throughout the second decade and the crop entered the winter in generally good shape; snow was needed in some parts of the Rocky Mountain region, while the continued dry weather in the Pacific Northwest was very detrimental. Although there was only a light snow cover over parts of the winter-wheat belt during the last decade, no apparent damage was reported from the severe weather, and at the close of the month a fairly good cover over most parts afforded protection; droughty conditions still prevailed over the Pacific Northwest.

Corn and cotton.—Husking and cribbing corn was delayed during the first decade by frequent precipitation and wet fields; there was some improvement during the second decade, but many places were still too wet. During the last decade the cold weather which overspread the Corn Belt was beneficial in drying out the crop locally, while the frozen ground aided hand husking, although in some parts the rough fields made machine husking difficult.

The wet, cloudy weather during the first decade made the gathering of the remaining cotton difficult, especially in the western belt, and there were complaints of stained and damaged staple. Frequent rains during the second decade were detrimental to cotton picking, although some progress was made in the northeastern belt. During the last decade considerable advance was noted in gathering the remaining crop in the northern portions of the belt, while the absence of rain in Texas made better conditions for scrapping.

Miscellaneous crops.—Meadows and ranges were largely in satisfactory condition in most places east of the Rocky Mountains during the month, with some snow cover during the severe weather. Snows were beneficial in parts of the Rockies, while some range remained open, permitting much grazing. The continued dry conditions in the more western States caused marked deterioration of the range.

Winter and fall truck crops did well during most of the month, although there were some reports of sweet potatoes rotting in the ground in the Southeast, due to continued wet weather. More or less frost damage to truck occurred toward the close of the month in the Southeast. Citrus continued to do well generally.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

While over the ocean as a whole the number of days on which gales occurred did not differ materially from the normal as shown on the Pilot Chart, there were few days in the month in which heavy weather was not encountered over some part of the northern section of the ocean and the gales were exceptionally severe over the steamer lanes during the latter half. The Icelandic LOW was unusually active during the greater part of the month as indicated by the marked negative departures at the three land stations on the British Isles, shown in Table 1.

During the greater part of the first two decades the Azores HIGH was well developed, although on the 1st and 2d an intrusion of low pressure was responsible for a disturbance in that region that will be referred to later.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean, November, 1929*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.54	(1)	30.12	12th	28.54	17th.
Belle Isle, Newfoundland	29.78	[2] −0.10	30.50	1st	28.60	16th.
Halifax, Nova Scotia	30.01	[3] +0.08	30.58	1st	29.12	28th.
Nantucket	30.04	[3] +0.02	30.44	23d	29.18	28th.
Hatteras	30.10	[3] −0.02	30.38	22d	29.58	28th.
Key West	30.02	[3] −0.03	30.10	10th [4]	29.92	28th.
New Orleans	30.12	[3] −0.03	30.42	30th	29.90	13th.
Cape Gracias, Nicaragua	29.90	[3] −0.03	29.90	10th [4]	29.80	1st.[4]
Turks Island	30.04	[3] +0.05	30.12	15th	29.92	17th.
Bermuda	30.08	[3] 0.00	30.34	1st	29.74	10th.[4]
Horta, Azores	30.19	[3] +0.09	30.60	11th	29.46	26th.
Lerwick, Shetland Islands	29.44	[2] −0.26	30.06	1st	28.76	12th.
Valencia, Ireland	29.56	[2] −0.33	30.28	1st	28.78	22d.
London	29.94	[2] −0.20	30.46	4th	29.27	30th.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other date or dates.

The number of days with fog was apparently considerably below normal over the greater part of the ocean. It was reported on from 6 to 9 days over the Grand Banks, from 4 to 6 days along the American coast north of Hatteras, and from 2 to 3 days in the Gulf of Mexico. Over the steamer lanes between the tenth and fortieth meridians fog did not occur on more than two days in any 5°-square; it was reported on three days off the coast of Spain and Portugal, while the British Isles were comparatively clear.

The first disturbance of any intensity in southern waters occurred on the first and 2d when a well-developed LOW was over the region between the Azores and Bermudas, with moderate to strong gales over a limited area near the center.

From the 4th to 10th heavy weather was the rule over the middle and eastern sections of the steamer lanes, although the storm area varied considerably in extent and intensity from day to day. On the 9th and 10th there was also a disturbance of marked intensity between the Bermudas and Nantucket, and on the latter date northerly winds of force 7 to 10 were reported from the westerly quadrants.

From the 11th to 13th land stations in northern Europe reported barometric readings well below 29 inches, and on the 11th and 12th strong westerly to northwesterly gales prevailed between the 30th meridian and British coast.

On the 14th to 16th a storm area covered the region from the 25th meridian to the coast of southern Europe, and on the latter day gales were also encountered in the vicinity of the Azores.

From the 17th to 29th the steamer lanes were swept by one severe disturbance after another, the storm area at times extending from the 10th to 55th meridians.

Charts VIII to XI cover the period from the 24th to 27th, when winds of force 11 and 12 were encountered by a number of vessels, as shown by reports in table.

OCEAN GALES AND STORMS, NOVEMBER, 1929

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
North Atlantic Ocean—			° ′	° ′				*Inches*					
Yuri Maru, Jap. S. S.	Oran	Boston	39 45 N.	45 30 W.	Oct. 31	7 p., 1	Nov. 2	29.83	NE	NE., 8	NNE	NE., 9	
Bird City, Am. S. S.	Copenhagen	Baltimore	55 45 N.	30 10 W.	31	2 p., 1	2	29.71	W	WSW., 8	W	WSW., 9	Steady.
Oranian, Br. S. S.	Liverpool	Barbados	33 00 N.	37 14 W.	Nov. 3	8 p., 3	4	29.86	SE	SE., 8	Var	SE., 10	SE.-S.-SSW.
Sagaporack, Am. S. S.	Norway	Portland, Me.	59 06 N.	10 10 W.	7	8 p., 7	12	28.74	SW	S., 8	NW	—, 10	WSW.-WNW.
Exmouth, Am. S. S.	Casablanca	New York	38 08 N.	67 04 W.	9	10 a., 9	10	29.61	N	—, 10	N	—, 10	NW.-N.-NNE.
Dordrecht, Du. S. S.	Helsingfors	do	49 10 N.	41 00 W.	10	Noon, 10	10	29.31	S	WSW., 9	N	WSW., 9	Steady.
Duquesne, Am. S. S.	Manchester	New Orleans	51 20 N.	8 00 W.	11	3 a., 11	16	29.77	WSW	WSW., 8	WSW	—, 10	WSW.-W.-NW.
Henri Jasper, Belg. S. S.	Antwerp	New York	50 30 N.	18 30 W.	14	2 a., 15	15	29.59	SSE	SW	NNW	N., 11	SW.-W.
Loriga, Br. M. S.	London	Canal Zone	48 38 N.	6 28 W.	15	—, 15	16	28.78	S	W	NNW	W., 10	Steady.
Stuttgart, Ger. S. S.	New York	Bremerhaven	44 10 N.	52 51 W.	16	9 a., 16	18	29.15	W	W., 9	W	W., 11	Do.
Norwegian, Br. S. S.	Liverpool	Boston	50 38 N.	42 25 W.	16	3 a., 17	19	28.93	SE	SW., 11	NW	SW., 11	SW.-WNW.
Bellflower, Am. S. S.	Cork	New York	51 25 N.	23 09 W.	17	Noon, 17	24	29.07	SSE	SSE	N	NW., 11	WSW.-NW.
Milwaukee, Ger. S. S.	Bishop's Rocks.	do	50 00 N.	13 50 W.	18	11 a., 18	18	29.39	S	SSW	WSW	SSW., 10	SSW.-WSW.
Coaxet, Am. S. S.	Houston	Liverpool	46 25 N.	26 01 W.	21	10 a., 21	21	29.14	NW	WNW, 11		WNW., 11	WNW.-NW.
Quaker City, Am. S. S.	Dundee	Philadelphia	57 10 N.	24 25 W.	22	6 p., 22	26	28.86	NE	NW., 9	NW	—, 11	
Grete, Ger. S. S.	Savannah	Bremen	48 30 N.	25 30 W.	21	9 p., 24	26	28.84	NW	WNW, 11	W	—, 11	NW.-W.
Sarcoxie, Am. S. S.	Havre	New York	40 55 N.	65 22 W.	25	6 a., 25	25	29.68	W	W., 7	NW	NW., 10	
Quaker City, Am. S. S.	Dundee	Philadelphia	49 30 N.	45 00 W.	26	6 p., 26	29	28.53	NW	NW, 9	W	—, 12	
Sundance, Am. S. S.	Savannah	Liverpool	47 00 N.	25 00 W.	26	6 a., 26	27	28.56	SE	SE., 7	S	SE., 12	SE.-S.
Antinous, Am. S. S.	Mobile	Bremen	44 25 N.	43 08 W.	26	4 a., 27	28	29.10	W	W	NW	—, 11	
Naples Maru, Jap. S. S.	Hamburg	New York	44 25 N.	48 07 W.	21	9 a., 28	29	28.96	WNW	WNW, 11	NW	NW., 12	
North Pacific Ocean—													
Taiyo Maru, Jap. S. S.	Yokohama	San Francisco	24 50 N.	165 38 W.	2	2 a., 4	4	29.74	NNE	SSW., 4	SW	N., 8	Steady.
California, Am. S. S.	Otaru	do	46 00 N.	161 00 E.	3	5 p., 3	3	29.47	WSW	W., 9	NW	WSW., 9	WSW.-WNW.
Chief Capilano, Br. S. S.	Karatsu	San Pedro	49 30 N.	172 00 W.	4	2 a., 4	4	28.92	S	SSW., 9	SW	SE., 11	S.-SSW.-WSW.
City of Victoria, Can. S. S.	Grays Harbor	Yokohama	52 20 N.	168 50 W.	4	4 p., 4	5	28.89	SE	SSW., 9	WSW	SSW., 9	S.-SSW.-WSW.
Kurohime Maru, Jap. S. S.	Everett	Kobe	50 40 N.	178 00 E.	5	6 a., 5	6	29.36	W	W., 8		W., 10	
Do	do	do	48 00 N.	165 30 E.	8	11 p., 8	9	29.25	W	W., 8		W., 9	
Golden Hind, Am. S. S.	Hong Kong	San Francisco	47 29 N.	179 03 E.	8	Noon, 8	8	29.52	S	S., 9	W	S., 9	S-W.
California, Am. S. S.	Otaru	do	46 38 N.	159 00 W.	8	5 p., 9	9	29.82	SSE	SSW., 8	W	S., 10	Do.
Do	do	do	46 55 N.	152 30 W.	10	6 a., 11	11	29.04	SE	S., 11	SW	S., 11	S.-SW.

OCEAN GALES AND STORMS, NOVEMBER, 1929—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
North Pacific Ocean—Continued			° ′	° ′				Inches					
Yokohama Maru, Jap. S. S.	Victoria	Yokohama	51 43 N.	172 28 W.	8	4 a., 10	10	28.76	S	SW., 10	NW	SW., 11	
Pres. Jefferson, Am. S. S.	do	do	50 54 N.	178 50 W.	8	Noon, 8	10	28.95	SW	SSE., 10	W	W., 10	SSE.-SE.
City of Victoria, Can. S. S.	Grays Harbor	do	50 50 N.	177 12 E.	9	10 a., 9	10	28.91	SSE	SW., 7	W	WSW., 11	SSE.-SW.
Emp. of Russia, Br. S. S.	Victoria	do	50 17 N.	175 41 E.	9	8 a., 9	10	28.96	SSE	SSW., 9	W	W., 12	5 points.
Golden Wall, Am. S. S.	Shanghai	San Francisco	47 50 N.	153 00 W.	9	9 p., 10	11	29.24	SSW	SSW., —	SW	SW., 9	SSE.-SSW.
Golden Dragon, Am. S. S.	Hong Kong	do	22 05 N.	121 08 E.	10	4 p., 11	11	30.02	NE	NE., 8	NE	NE., 8	Steady.
William Penn, Am. M. S.	Nagoya	San Pedro	44 50 N.	167 15 E.	10	4 a., 11	13		NNW	NW., 8	NW	NW., 9	NNW.-WNW.
Tacoma, Am. S. S.	Hong Kong	San Francisco	45 06 N.	143 25 W.	11	1 p., 11	12	29.72	SSE	S., 9	SSW	S., 9	S.-SSW.
West Montop, Am. S. S.	Philadelphia	Seattle	13 20 N.	93 35 W.	16	4 p., 16	17	29.77	NNW	NNW., 8	NNE	N., 8	NNW.-NNE.
Juyo Maru, Jap. S. S.	Miike	Vancouver	48 35 N.	176 30 E.	16	8 a., 17	17	29.53	SSE	SE., 8	S	SE., 9	SE.-S.-SW.
William Penn, Am. M. S.	Nagoya	San Pedro	46 26 N.	149 53 W.	17	1 p., 18	19	28.94	ENE	SE., 9	S	S., 9	SE.-S.
Iyo Maru, Jap. S. S.	Yokohama	Victoria	40 03 N.	150 43 E.	18	8 p., 18	21	29.51	S	SSW., 7	NW	WNW., 10	
Toyama Maru, Jap. S. S.	do	do	41 55 N.	155 03 E.	21	4 p., 22	23	29.29	W	WNW., 10	NW	WNW., 10	WNW.-NW.
San Julian, Am. S. S.	San Pedro	Balboa	15 53 N.	95 30 W.	23	Noon, 23	24	29.78	NE	NE., 6	N	NE., 9	Steady.
Olympia, Am. S. S.	Otaru	San Francisco	43 54 N.	162 40 E.	28	11 a., 28	28	28.94	E	NE., —	NW	NE., 9	ENE.-NE.
Admiral Rogers, Am. S. S.	Seattle	Kodiak	58 54 N.	151 48 W.	28	2 p., 28	28	29.82	NE	NE., 7		—, 8	
Koyo Maru, Jap. S. S.	Miike	San Pedro	41 29 N.	165 23 W.	28	8 p., 28	29	29.50	S	S., 9	SW	S., 9	S.-SSW.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

At the beginning of November atmospheric pressure was above 30 inches over most of the Aleutian region west of the Alaska Peninsula, but after the 1st or 2d of the month cyclonic conditions entered and became increasingly active for nearly two weeks. By the 8th a disturbance of great energy had developed, with central pressures below 29 inches. It gradually spread eastward, until by the 11th it had covered most of the upper waters of the ocean. Thereafter it diminished as an oceanic cyclone, but an offshoot from it entered British North America as a traveling cyclone and later crossed to the Atlantic Ocean between Newfoundland and Greenland. Cyclonic conditions of variable energy prevailed over the northern Pacific until the end of the month, again attaining considerable intensity on the 29th and 30th. The average center of the Aleutian cyclone this month lay over the eastern part of the Bering Sea.

The California-Pacific anticyclone crested on the average nearly midway between Oregon and the Hawaiian Islands. Owing to the frequent southward extension of the northern cyclone along longitudes 155° to 165° W., the HIGH was divided by a shallow trough of low pressure, another anticyclonic crest appearing in the neighborhood of Midway Island.

Farther west high pressure overlay the China coast, resulting in a frequent strong northeast monsoon current from the China Sea northward, sometimes, as on the 2d to 4th, and the 10th and 11th, south of Taiwan, acquiring the force of a fresh gale.

Barometric data for several island and coast stations in west longitudes, including Point Barrow in the Arctic Ocean, are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, November, 1929*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow [1] [2]	30.10		30.68	18th	29.40	25th.
Dutch Harbor [1] [3]	29.45	−0.14	30.24	16th	28.54	30th.
St. Paul [1] [3]	29.40	−0.22	30.14	2d	28.54	10th.[6]
Kodiak [1]	29.60	+0.06	30.36	18th	28.46	12th.
Midway Island [1]	30.16	+0.09	30.34	2d	29.96	28th.[6]
Honolulu [4]	29.99	−0.03	30.07	7th	29.83	20th.
Juneau [4]	29.75	−0.01	30.36	6th	29.19	15th.
Tatoosh Island [4] [5]	30.07	+0.10	30.38	31st	29.64	16th.
San Francisco [4] [5]	29.99	−0.11	30.14	11th	29.84	28th.
San Diego [4] [5]	29.92	−0.08	30.02	31st	29.66	28th.

[1] P. m. observations only.
[2] For 27 days.
[3] For 29 days.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.
[6] And on other days.

Despite the rather severe aspects of the northern cyclones on several days, somewhat fewer gales disturbed the upper steamship routes than in October. This was due in part to the absence of typhoons in eastern Japanese waters and in part to the shifting westward since October of the central storm region from the Gulf of Alaska to the Aleutians and the Bering Sea. Very few gales, consequently, were encountered over the eastern portion of the routes. Along the central portion, in spite of the storm concentration there, conditions generally were not as rough as in October, although storm to hurricane forces were experienced by vessels on the 4th, 9th, 10th, and 11th. These gales occurred mostly south of the Aleutians, except that of the 11th, which was near latitude 46° N., longitude 153° W. The gales of the 9th to the 11th show the progressive nature for those days of the more violent portion of the disturbance of the 8th to 16th, the earliest

occurring south of the western Aleutians, that of the 10th south of the central Aleutians and that of the 11th some 20° farther east. Other gales of lesser intensity for this general region are given in the gale and storm report.

Few gales of consequence seem to have occurred off the Japanese coast, the nearest reported by vessels being, on the 7th and 27th, near 41° N., 148°-150° E., and not exceeding 8 in force. In the general neighborhood of Midway Island fresh gales occurred on the 2d, 3d, 16th, 24th, and 29th, due to disturbances of a minor nature.

In the oriental tropics no gales other than anticyclonic were reported. However, toward the end of the month a depression that may on two or three days have threatened to become a typhoon lay to the westward of Guam, and still existed as a LOW in practically the same position on the 30th.

In the Mexican tropics northers of moderate to fresh gale force blew over the Gulf of Tehuantepec on the 3d, 8th, 12th, 15th, 16th, and 17th and of strong gale force on the 23d. These arose from strong anticyclonic conditions moving southward over the United States. Off the middle portion of Lower California a fresh gale occurred on the 13th.

The weather was quiet in the Hawaiian area, the nearest reported gales, of fresh force only, occurring 500 or more miles northeast and northwest of the islands on the 20th and 24th, respectively. At Honolulu the prevailing wind was from the east, and the maximum velocity at the rate of 22 miles an hour from the east on the 5th.

Fog in itself was rather rare over the main body of the ocean, although thick weather, due to rain, snow, sleet, or hail, was somewhat frequent, particularly during accentuations of the Aleutian cyclone in upper central longitudes. Scattered fog formed during several days of the last decade south of the Gulf of Alaska and on the 29th and 30th in the Bering Sea. Along the American coast fog was reported on about 40 per cent of the days off Washington, 50 per cent off Oregon and northern California, and about 90 per cent off central California, the last showing an extraordinary rate of occurrence. Southward the phenomenon decreased with great rapidity to the middle west coast of Lower California. Smoke also added to the difficulties of navigating along a part of our coast, as may be seen by the report of Second Officer T. A. Jones, of the American steamship *Admiral Peoples*. He said:

> From Columbia River light vessel, November 20, 4 a. m., to Piedras Blancas, November 24, 4 a. m., dense smoke causing visibility to become so low at times it was necessary to sound vessel's whistle. Smoke due to fires along Oregon and California coast.

FOG IN THE GULF OF TEHUANTEPEC, NOVEMBER, 1929

By WILLIS E. HURD

In November, 1929, several remarkable instances of fog occurred in the Gulf of Tehuantepec. They approximated in frequency those interesting and meteorologically historic occurrence in the gulf during the winter of 1924-25, especially in February, which excited such comment among seamen and others within and outside the port of Salina Cruz coincident with the time of the excessive rainfalls over Peru. At that time an unusual number of patches and streams of cold water were reported welling up at points off the lower Mexican coast. These resulted in local condensations of fog, and the present instances are to be accounted for similarly. The fogs which received the most particular comment occurred on the 27th, 29th, and 30th, and excerpts are here given from the meteorological reports of the following vessels for those days:

American steamship *Sagadahoc;* H. R. S. Sinclair, second officer and observer; Los Angeles to Balboa:

> At 2:15 a. m., November 27, 1929, in latitude 14° 45′ N., longitude 96° 20′ W., we entered an area of dense fog. * * * The water at the injection was still 80°; at the surface it was 73°, while the air remained at 75°. When the fog cleared away at 6 a. m., the water at injection was 80°; at the surface it had risen to 76°, and the air had also risen to 76°. * * * The fog seemed to descend from above. I saw it first swirling around the masthead and range lights, and then around the side lights. * * * At first it was dead calm, and I estimated the clear patches, from which the fog stood back, rising like a solid wall of gray out of the black water, to be from 500 to 1,000 feet in diameter. We were making a speed of about 10 knots and crossed these patches in from one to two minutes. Then the fog would engulf us again in billowing waves. At these times it was so dense it could be seen swirling in the back draft of a rapidly moved hand.
>
> As you see, we have joined the small group of mariners who have had the unusual experience of encountering fog in this part of the world, and we are interested to know if any other ship in the vicinity met similar conditions at that time.

American tanker *S. C. T. Dodd;* master, L. C. Hansen; observer, O. H. Friz, second officer; Balboa to San Pedro:

> At midnight, while in latitude 14° 22′ N., longitude 93° 31′ W., observed a change in temperature from 80° to 76° (air) and 82° to 70° (water). Wind south 1. * * * At 1:50 a. m., L. M. T., observed a bank of dense fog extending from SW. to NE. At 1:54 a. m. entered bank of dense fog. Temperature air 76°, water 70°. Sea smooth and calm. Fog came in patches and at times very dense, with maximum visibility estimated at 200 feet. * * * Dense fog occasionally opened up overhead, revealing stars. Patches of light fog usually did not reach greater height than 55 feet above sea level, evidence of which was diffusion of the side lights at approximate height of 50 feet, whereas masthead light and range lights at approximate heights of 100 and 115 feet, respectively, shone bright and clear. At times ship found herself in areas of 1 or 2 square miles free of fog, but surrounded by low banks of brown fog. Fog lifted at 9:23 a. m., November 29. Fog carried with it a remarkably strong odor of decaying seaweed.
>
> Approaching the coast of Mexico, noted banks of heavy brown fog covering the coast in the vicinity of Port Angeles and Santa Cruz Harbor.

American steamship *Robin Gray;* master, H. M. Okland; observer, P. Waetge, chief officer; Columbia River to Panama:

> Fog banks had been observed already the day before shortly before sunset, and appeared suddenly at 3:20 a. m., November 30, and was a very thick low blanket on the water, clearing as suddenly at 6:50 a. m. When ship entered the fog, the temperature of the sea water had dropped from 84° to 72°; was 73° when leaving the fog blanket, and rose then within 30 minutes to 81°. Left fog in latitude 14° 17′ N., longitude 94° 30° W.

CLIMATOLOGICAL TABLES [1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, November, 1929

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	54.4	+0.3	Evergreen	88	1	Valley Head	10	[2] 29	10.00	+6.92	Helena	20.59	Newton	3.22
Arizona	49.4	−3.2	3 stations	89	[2] 3	Pinedale	−2	25	0.13	−0.72	Portal	1.10	41 stations	0.00
Arkansas	46.1	−5.5	Rison	85	12	Dutton	7	30	2.61	−1.04	Helena	6.57	Mountain Home	0.78
California	52.9	+1.4	Middlewater	98	[2] 3	Portola	0	[2] 8	T.	−2.47	Crescent City	0.11	245 stations	0.00
Colorado	27.7	−7.8	Ignacio	77	29	Fraser	−28	13	0.86	+0.11	La Veta Pass	3.86	2 stations	0.04
Florida	68.8	+3.7	Venus	92	8	Mount Pleasant	21	30	1.64	−0.55	Pensacola	7.04	Jacksonville	0.08
Georgia	56.5	+2.0	Alapaha	91	3	2 stations	8	30	4.95	+2.30	Resaca	14.78	Brunswick	0.39
Idaho	32.6	−3.2	4 stations	68	[2] 3	Warren	−12	21	0.15	−1.87	Irwin	1.10	12 stations	0.00
Illinois	37.8	−4.3	Carbondale	73	10	Mascoutah	−8	30	1.81	−0.59	Flora	3.60	Galena	0.74
Indiana	38.6	−3.6	2 stations	75	[2] 1	Marengo	−9	30	2.71	−0.38	Madison	4.88	Farmersburg	1.13
Iowa	32.3	−4.3	Ottumwa	66	11	Webster City	−12	30	1.24	−0.31	Williamsburg	2.58	Lake Park	0.08
Kansas	35.7	−8.2	Garden City	76	5	Burr Oak	−19	22	1.61	+0.47	Medora	3.99	Lawrence	0.38
Kentucky	44.6	−1.8	Harlan	81	1	Shelbyville	−9	30	4.03	+0.46	Middlesboro	7.82	Owensboro	2.13
Louisiana	54.8	−4.1	3 stations	87	[2] 1	Plain Dealing	17	23	9.99	+6.41	Baton Rouge	20.24	Shreveport	1.99
Maryland-Delaware	46.1	+1.5	Newburg, Md.	85	2	2 stations	−7	30	2.62	+0.08	Grantsville, Md.	5.14	Great Falls, Md.	1.65
Michigan	33.4	−2.9	L'Anse	69	1	3 stations	−12	29	1.74	−0.64	Painesdale	4.54	Howard City	0.20
Minnesota	25.7	−4.0	2 stations	61	[2] 16	Roseau	−29	[2] 29	0.55	−0.50	Ada	1.45	Beardsley	0.14
Mississippi	52.8	−2.3	Hattiesburg	86	2	Duck Hill	12	30	8.61	+5.19	Monticello	19.73	Bay St. Louis	3.70
Missouri	39.0	−5.4	Caruthersville	78	12	Clifton Hill	−8	30	1.46	−0.96	Sikeston	4.47	Hailey	0.11
Montana	30.4	−1.6	6 stations	68	[2] 4	Red Lodge	−24	21	0.58	−0.39	Red Lodge	3.04	Hamilton	0.01
Nebraska	31.6	−5.1	Kearney	76	[2] 16	Ewing	−19	[2] 22	0.98	+0.24	Weeping Water	2.32	Bradshaw	0.10
Nevada	39.9	−1.0	Clay City	95	2	Owyhee	−10	21	0.02	−0.62	Mahoney Ranger Station.	0.40	40 stations	0.00
New England	38.3	+0.4	Waterbury, Conn.	80	2	Plymouth, N. H.	−7	29	2.75	−0.73	Bar Harbor, Me.	4.67	Bethlehem, N. H.	0.86
New Jersey	44.5	+1.6	Indian Mills	83	2	Newton	4	30	2.73	−0.32	Tuckerton	3.64	Sandy Hook	2.08
New Mexico	36.1	−6.2	3 stations	80	[2] 6	Elisabethtown	−18	22	0.76	+0.13	Quay	2.44	4 stations	0.00
New York	38.7	+1.1	Port Jervis	78	2	North Lake	−6	23	3.01	+0.14	Stillwater Reservoir	6.37	2 stations	1.58
North Carolina	51.6	+2.0	5 stations	85	[2] 3	Mount Mitchell	−21	30	4.47	+2.15	Highlands	11.06	Wilmington	1.63
North Dakota	24.8	−1.8	Arnegard	70	16	Langdon	−21	28	0.53	−0.05	2 stations	1.60	Stowers	T.
Ohio	39.0	−2.4	Middleport	81	[2] 1	Bangorville	−5	30	3.81	+1.05	Philo (No. 2)	5.40	Bellefontaine	2.14
Oklahoma	42.7	−7.7	Miami	79	11	Boise City	−6	22	2.05	+0.08	Alva	3.73	Chattanooga	0.94
Oregon	39.6	−2.1	Brookings	88	2	Blitzen	−12	11	0.38	−4.14	Astoria	2.08	8 stations	0.00
Pennsylvania	41.1	+0.1	3 stations	81	[2] 1	Elk Lick	−10	30	3.39	+0.58	Pennline	5.07	Weikert	1.89
South Carolina	54.7	+1.0	Sumter	90	3	Caesars Head	2	30	3.85	+1.56	Caesars Head	9.22	Pinopolis	1.20
South Dakota	29.3	−4.5	Ottumwa	72	17	Redig	−19	21	0.60	−0.07	Dumont	3.34	Canton	T.
Tennessee	47.4	−1.0	2 stations	83	1	2 stations	0	30	6.18	+2.56	Rugby	13.57	Dover	2.45
Texas	50.4	−6.7	Riogrande	93	12	Vega	−4	[2] 22	3.10	+0.76	Beaumont	15.32	8 stations	0.00
Utah	34.4	−3.3	St. George	77	[2] 3	Soldier Summit	−6	22	0.14	−0.80	Logan	0.93	24 stations	0.00
Virginia	47.9	+1.3	Emory	88	2	Dante	−2	30	3.35	+0.78	Speers Ferry	6.17	Staunton	1.22
Washington	37.1	−2.7	Longmire	76	4	2 stations	−3	21	0.85	−3.61	Neah Bay	5.03	16 stations	0.00
West Virginia	42.9	−0.1	Williamson	83	2	Pickens	−9	30	4.52	+1.71	Horner	8.10	Romney	1.74
Wisconsin	29.6	−3.8	High Falls	67	1	Solon Springs	−22	30	0.88	−0.91	Deerskin Dam	1.95	Mondovi	0.16
Wyoming	24.4	−6.6	Dubois	67	16	Riverside	−38	21	0.95	+0.28	Dome Lake	3.50	Pinedale	0.08
Alaska [October]	31.0	+1.8	Kodiak (a)	74	4	Shaktoolik	−18	[2] 28	4.44	+0.95	Latouche	32.83	Nyac	0.06
Hawaii	72.1	+0.4	Kalawao	92	20	3 stations	51	[2] 23	12.65	+4.22	Awini	31.48	Insane Asylum	2.05
Porto Rico	76.2	−0.6	Canovanas	95	1	Guineo Reservoir	55	6	3.77	−3.65	Rio Grande	13.47	Coamo	0.60

[1] For description of tables and charts, see REVIEW, January, 1929, p. 36.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, November, 1929*

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	°F.		°F.	°F		°F.	° F.	° F.	° F.	%	In.	In.		Miles								0-10	In.	In.
New England							41.0	+1.5										73	2.75	-0.4										6.9		
Eastport	76	67	85	29.89	29.98	-0.03	37.0	+0.3	57	2	43	10	30	31	31	34	29	72	2.25	-1.1	12	6,263	w.	41	e.	18	4	8	18	7.3	1.1	T.
Greenville, Me.	1,070	6	.....	28.78	29.97	.....	31.0	.....	57	2	38	-5	30	24	24	.....	.....	.....	2.13	.....	11	5,190	se.	36	.....	25	6	4	20	.....	3.0	.....
Portland, Me.	103	82	117	29.90	30.03	+.02	39.6	+1.6	70	2	46	10	30	33	26	35	30	73	4.55	+1.1	12	5,040	sw.	25	nw.	29	6	6	18	6.9	3.9	T.
Concord	289	70	79	29.69	30.01	-.05	37.6	-0.1	70	2	46	7	23	29	32	.....	.....	.....	2.37	-0.7	13	3,284	nw.	24	w.	28	4	8	18	7.2	1.5	0.0
Burlington	403	11	48	29.53	29.98	-.07	36.6	+0.3	63	2	43	9	29	31	24	.....	.....	.....	2.24	-0.4	12	7,721	s.	44	s.	26	3	7	20	7.9	0.9	T.
Northfield	876	12	60	.....	30.01	-.04	34.0	+1.2	67	2	43	-2	23	25	32	.....	.....	80	1.12	-1.8	15	4,332	sw.	23	sw.	19	2	3	25	8.7	2.6	0.4
Boston	125	106	165	29.91	30.05	.00	44.7	+2.7	77	2	51	12	30	38	21	39	33	69	3.01	-0.3	12	5,098	w.	27	nw.	15	9	8	13	6.4	3.0	0.0
Nantucket	12	14	90	30.02	30.03	-.02	46.2	+1.8	65	2	51	20	30	41	18	42	38	76	3.86	+0.6	13	9,648	w.	40	e.	18	4	10	16	7.1	T.	0.0
Block Island	26	11	46	29.99	30.02	-.04	45.8	+1.2	64	2	50	20	30	41	19	42	38	77	3.48	-0.2	14	11,539	w.	56	nw.	28	8	9	13	6.5	T.	0.0
Providence	160	215	251	29.86	30.04	-.03	43.6	+3.2	74	2	50	13	30	37	21	39	33	70	2.47	-0.6	13	6,475	nw.	44	n.	15	11	5	14	5.8	0.9	0.0
Hartford	159	122	.....	29.87	30.05	-.03	42.6	+3.1	77	2	50	11	30	36	25	.....	.....	.....	2.64	-0.9	12	.....	nw.	.....	.....	.....	7	7	16	6.5	1.3	0.0
New Haven	106	74	153	29.94	30.06	-.01	43.6	+1.6	75	2	50	11	30	37	19	39	33	70	2.22	-1.1	13	5,403	n.	27	w.	28	10	8	12	5.7	0.2	0.0
Middle Atlantic States							46.1	+1.4										75	2.74	+0.1										6.6		
Albany	97	107	115	29.92	30.04	-.04	41.2	+1.9	67	2	48	13	30	35	22	38	34	78	1.82	-1.0	13	4,287	s.	23	sw.	26	8	10	12	6.1	T.	0.0
Binghamton	871	10	84	29.08	30.02	-.07	40.4	+1.7	68	1	47	7	30	34	26	.....	.....	.....	2.73	+0.3	14	3,885	w.	21	sw.	30	2	12	16	7.7	1.6	T.
New York	314	414	454	29.72	30.06	-.03	46.0	+1.8	73	2	52	11	30	40	21	41	35	69	2.08	-0.9	11	10,103	w.	48	nw.	28	3	12	15	7.4	T.	0.0
Bellefonte	1,050	5	36	28.93	30.06	.....	38.0	.....	70	1	46	2	30	30	29	34	31	81	2.66	.....	10	.....	w.	.....	.....	.....	4	9	17	7.2	0.9	0.5
Harrisburg	374	94	104	29.69	30.10	-.01	43.7	+0.9	72	1	50	10	30	38	22	39	34	71	2.82	+0.6	12	4,187	w.	23	sw.	30	7	9	14	6.6	0.2	0.0
Philadelphia	114	123	367	29.96	30.09	-.01	47.4	+1.7	77	2	53	14	30	42	20	43	38	72	3.11	+0.4	10	8,273	sw.	36	w.	28	6	9	15	6.6	T.	0.0
Reading	325	81	98	29.72	30.08	.....	44.8	.....	76	2	51	11	30	38	25	40	35	70	2.95	+0.2	10	3,979	w.	21	nw.	28	8	8	14	6.6	T.	0.0
Scranton	805	111	119	29.18	30.06	-.03	41.6	+1.1	69	1	48	6	30	35	25	37	33	75	2.62	-0.2	14	4,451	sw.	31	w.	28	2	14	14	7.4	0.3	T.
Atlantic City	52	37	172	30.02	30.08	-.02	47.4	+1.8	69	15	53	14	30	42	21	44	40	77	3.19	+0.4	13	10,259	w.	37	w.	28	7	10	13	6.3	0.4	0.0
Cape May	17	13	49	.....	.....	.....	48.2	+0.8	76	2	55	16	30	42	24	45	41	79	2.48	-0.7	11	.....	nw.	.....	.....	.....	4	13	13	.....	2.1	0.0
Sandy Hook	22	10	55	30.03	30.06	.....	45.8	.....	72	2	51	14	30	41	18	42	37	74	2.08	-1.2	11	102,94	sw.	42	sw.	28	7	9	14	6.4	T.	0.0
Trenton	190	159	183	29.86	30.07	.....	45.3	.....	76	2	52	12	30	38	22	41	36	73	2.24	-0.5	11	6,635	sw.	37	w.	28	7	8	15	6.5	T.	0.0
Baltimore	123	100	215	29.95	30.09	-.02	48.3	+2.0	82	2	55	12	30	42	23	43	38	72	2.44	-0.1	13	6,322	sw.	36	sw.	28	8	9	13	6.3	0.3	0.0
Washington	112	62	85	29.97	30.10	-.02	47.6	+2.4	83	2	55	11	30	40	25	42	37	73	1.70	-0.7	14	3,972	nw.	25	nw.	28	8	5	17	6.7	1.1	0.0
Cape Henry	18	8	54	30.07	30.09	.....	53.5	.....	83	2	60	19	30	47	25	49	45	77	3.25	+0.9	9	8,271	sw.	38	n.	5	8	9	13	6.0	T.	0.0
Lynchburg	681	153	188	29.36	30.12	-.01	48.0	+0.8	79	2	56	9	30	40	31	43	39	75	2.82	+0.5	13	4,597	w.	30	nw.	28	10	6	14	6.0	3.5	0.0
Norfolk	91	170	205	30.01	30.11	.00	53.1	+1.7	80	2	60	17	30	47	20	48	43	75	3.66	+1.5	10	7,957	s.	31	nw.	30	8	6	16	6.3	T.	0.0
Richmond	144	11	52	29.96	30.12	.00	49.8	+1.5	81	2	58	14	30	42	27	45	40	76	3.34	+1.1	11	5,203	sw.	27	nw.	28	8	9	13	6.0	3.8	0.0
Wytheville	2,304	40	55	27.69	30.11	-.02	42.7	+0.3	74	2	50	0	30	36	27	39	36	80	4.07	+1.9	17	3,878	w.	30	w.	28	6	5	19	7.3	6.2	0.6
South Atlantic States							55.9	+1.8										80	2.90	+0.5										6.1		
Asheville	2,253	70	84	27.73	30.12	-.02	46.6	+1.5	71	2	53	4	30	40	31	43	40	82	2.43	+0.2	14	5,971	se.	26	n.	30	9	4	17	6.4	1.0	0.0
Charlotte	779	55	62	29.27	30.12	-.01	51.7	+1.1	78	2	59	15	30	45	26	47	43	80	4.31	+1.7	15	3,286	s.	15	sw.	17	9	3	18	6.6	T.	0.0
Greensboro	886	5	56	29.16	30.13	.....	48.4	.....	79	2	57	10	30	40	33	44	41	84	4.23	.....	13	4,906	sw.	29	sw.	28	8	4	18	6.5	T.	0.0
Hatteras	11	5	50	30.08	30.09	-.02	58.4	+2.1	78	2	63	26	30	54	22	55	52	83	3.22	-0.3	10	8,680	n.	33	n.	4	8	5	17	6.6	0.0	0.0
Raleigh	376	103	110	29.71	30.12	-.01	52.4	+1.4	80	2	60	15	30	45	24	47	43	77	4.82	+2.5	10	4,269	sw.	17	ne.	22	9	4	17	6.3	0.0	0.0
Wilmington	78	81	91	30.04	30.12	.00	57.0	+1.0	81	3	64	24	30	50	26	52	50	84	1.63	-0.3	7	4,000	n.	17	w.	18	13	5	12	5.4	0.0	0.0
Charleston	48	11	92	30.07	30.12	.00	60.0	+1.9	81	3	67	28	30	54	24	54	51	79	2.00	-0.1	9	6,509	ne.	25	ne.	23	11	6	13	5.3	0.0	0.0
Columbia, S. C.	351	41	57	29.74	30.13	+.01	55.4	+1.4	84	3	63	19	30	48	28	50	46	77	2.06	+0.1	12	4,210	ne.	22	sw.	27	10	4	16	6.1	0.0	0.0
Due West	711	10	55	29.36	30.14	.....	52.1	.....	80	2	59	16	30	45	30	.....	.....	.....	5.27	.....	14	5,391	ne.	25	w.	27	10	3	17	6.2	~~T.~~	0.0
Greenville, S. C.	1,039	139	146	29.00	30.11	.....	51.3	+1.7	75	2	58	15	30	45	25	47	43	79	5.50	+2.3	16	4,976	ne.	27	w.	27	10	1	19	6.4	0.0	0.0
Augusta	182	62	77	29.92	30.11	-.02	57.2	+2.7	85	3	65	21	30	49	29	51	47	78	4.13	+1.7	10	3,360	nw.	18	w.	27	7	5	18	6.5	0.0	0.0
Savannah	65	150	194	30.05	30.12	.00	60.4	+1.9	84	15	68	25	30	53	25	55	52	82	1.75	-0.4	5	7,249	s.	27	nw.	4	13	5	12	5.2	0.0	0.0
Jacksonville	43	209	245	30.04	30.10	.00	65.0	+2.8	84	3	73	28	30	58	24	58	55	80	0.08	-1.9	3	6,761	n.	30	ne.	5	8	13	9	5.3	0.0	0.0
Florida Peninsula							74.5	+3.5										81	1.10	-1.2										4.2		
Key West	22	10	64	29.99	30.01	-.01	76.9	+2.6	85	1	81	66	30	72	14	73	71	86	2.09	-0.1	12	6,221	e.	21	e.	1	16	12	2	3.7	0.0	0.0
Miami	25	141	168	30.02	30.05	-.02	76.0	+4.2	84	27	80	59	30	72	15	70	67	78	0.89	-2.0	9	6,400	e.	25	e.	16	10	14	6	4.7	0.0	0.0
Tampa	35	79	87	30.02	30.06	-.02	70.6	+3.7	88	8	79	39	30	62	24	64	61	80	0.32	-1.4	6	4,056	ne.	17	ne.	30	6	16	8	5.3	0.0	0.0
Titusville	44	5	.....	30.02	30.06	.....	70.4	.....	89	8	80	37	30	61	31	.....	.....	.....	0.46	.....	4	.....	nw.	.....	.....	.....	21	7	2	3.2	0.0	0.0
East Gulf States							55.8	-0.4										80	7.74	+4.5										6.3		
Atlanta	1,173	190	216	28.87	30.12	-.01	51.8	-0.3	75	1	58	14	30	46	34	47	43	77	6.26	+3.2	16	6,933	nw.	31	nw.	4	9	2	19	6.7	T.	0.0
Macon	370	78	87	29.73	30.13	.00	56.4	+2.2	82	3	64	20	30	49	29	51	47	79	5.20	+2.7	12	3,673	nw.	25	ne.	7	7	7	16	6.4	0.0	0.0
Thomasville	273	49	58	29.80	30.10	-.02	60.9	+2.4	86	2	69	24	30	53	25	55	52	80	1.73	-1.0	4	2,888	ne.	13	ne.	22	7	5	18	6.5	0.0	0.0
Apalachicola	36	42	49	30.05	30.09	.....	63.6	.....	79	3	70	30	30	58	24	59	57	83	0.93	-2.1	4	6,198	se.	26	n.	30	8	11	11	5.5	0.0	0.0
Pensacola	56	149	185	30.04	30.10	-.01	59.4	-0.8	77	3	65	26	30	54	34	56	53	83	7.04	+3.3	13	8,388	n.	30	w.	12	8	6	16	6.1	0.0	0.0
Anniston	741	9	57	29.34	30.14	+.02	52.4	+0.5	80	1	60	17	30	45	29	.....	.....	.....	11.72	+8.5	14	3,132	nw.	19	nw.	29	11	2	17	6.4	T.	0.0
Birmingham	700	11	48	29.36	30.14	+.02	52.6	-1.3	81	1	60	18	30	46	26	48	45	82	14.69	+11.4	14	4,370	n.	25	se.	14	9	2	19	6.7	T.	0.0
Mobile	57	125	161	30.04	30.10	-.01	58.4	-0.2	81	1	65	27	30	52	31	54	51	82	8.23	+4.6	13	6,863	n.	31	n.	29	8	7	15	6.1	0.0	0.0
Montgomery	223	100	112	29.87	30.13	+.01	56.4	+0.6	82	1	63	23	30	50	27	52	48	77	12.01	+8.8	15	4,246	n.	20	nw.	29	9	5	16	6.6	0.0	0.0
Corinth	469	6	.....	.....	.....	.....	50.0	.....	77	1	58	16	30	41	34	.....	.....	.....	6.04	.....	13	.....	nw.	.....	.....	.....	2	18	10	.....	5.5	0.0
Meridian	375	87	95	29.72	30.12	.00	53.8	-0.4	83	2	61	21	30	47	28	49	46	81	11.65	+8.3	15	3,509	n.	20	n.	29	8	5	17	6.4	0.0	0.0
Vicksburg	247	65	73	29.87	30.16	+.04	51.8	-4.8	78	10	58	20	30	45	27	47	43	80	8.31	+4.6	15	3,800	n.	24	w.	17	8	4	18	6.8	0.0	0.0
New Orleans	53	76	84	30.05	30.11	+.01	59.6	-2.0	84	2	66	31	30	53	24	55	52	81	5.16	+2.0	14	4,568	ne.	22	n.	29	10	5	15	5.6	0.0	0.0
West Gulf States							51.7	-6.0										76	3.84	+1.0										6.1		
Shreveport	249	77	93	29.88	30.16	+.05	49.9	-6.1	80	12	57	26	23	43	33	45	40	74	1.99	-1.7	12	3,572	n.	18	se.	9	9	5	16	6.3	2.0	0.0
Bentonville	1,303	11	44	28.73	30.13	+.02	40.7	-6.0	71	11	49	13	22	33	30	.....	.....	.....	1.42	.....	9	3,406	nw.	20	s.	25	15	2	13	.....	1.0	0.0
Fort Smith	457	79	94	29.66	30.15	+.04	45.2	-5.8	68	10	53	23	30	37	35	40	35	74	1.40	-1.5	10	4,432	e.	23	n.	28	9	6	15	6.3	T.	0.0
Little Rock	357	136	153	29.77	30.16	+.04	47.6	-4.5	74	12	55	22	30	40	28	41	35	67	1.85	-2.3	13	5,290	n.	34	n.	29	9	8	13	5.8	4.9	0.0
Austin	605	136	148	29.48	30.12	.....	52.4	-6.1	83	28	62	28	23	42	40	46	41	72	5.87	+3.6	9	5,451	n.	33	n.	12	10	8	12	6.0	0.0	0.0
Brownsville	57	83	100	30.02	30.08	.....	61.4	-5.8	84	8	69	40	22	54	34	56	54	81	1.72	-0.3	11	6,640	nw.	26	s.	12	7	6	17	6.7	0.0	0.0
Corpus Christi	20	11	78	30.08	30.10	+.03	59.0	-5.3	86	11	66	36	23	52	30	55	52	83	3.07	+1.1	12	7,067	n.	36	n.	29	8	4	18	6.9	T.	0.0
Dallas	512	220	227	29.59	30.16	.....	48.2	.....	75	28	56	28	23	41	31	.....	.....	.....	1.58	-1.0	6	7,683	n.	31	n.	3	11	6	13	5.6	1.6	0.0
Fort Worth	670	106	114	29.42	30.14	+.04	49.2	-6.3	82	11	58	26	23	40	38	43	38	72	1.50	-1.1	5	4,900	nw.	22	nw.	12	11	4	15	6.1	2.2	0.0
Galveston	54	106	114	30.07	30.13	+.04	56.6	-6.7	78	12	62	35	23	51	23	53	51	82	7.68	+4.4	17	7,280	n.	32	se.	1	10	7	13	6.0	0.0	0.0
Groesbeck	461	11	56	29.65	30.14	.....	49.6	.....	74	1	58	28	30	41	33	.....	.....	.....	6.62	+3.7	9	6,126	n.	28	ne.	20	9	8	13	5.9	T.	0.0
Houston	138	292	314	29.97	30.13	.....	55.0	-6.0	82	12	63	32	30	47	33	.....	.....	.....	5.30	+1.5	13	8,027	n.	33	n.	29	10	4	16	6.2	0.0	0.0
Palestine	510	64	72	29.61	30.16	+.05	49.4	-7.8	75	27	58	25	30	41	43	44	40	76	6.56	+3.1	10	4,320	n.	21	nw.	12	10	7	13	5.9	T.	0.0
Port Arthur	34	58	66	30.08	30.12	.....	54.8	.....	79	12	62	32	30	48	25	51	48	82	12.87	.....	14	5,703	e.	28	e.	21	8	5	17	6.5	0.0	0.0
San Antonio	693	119	132	29.39	30.12	+.04	55.0	-5.3	84	11	65	31	23	45	35	47	42	68	3.17	+1.3	9	4,598	ne.	25	ne.	29	10	6	14	6.1	0.0	0.0
Taylor	583	55	63	29.55	30.17	+.00	51.1	-6.6	79	11	60	27	30	42	37	.....	.....	.....	5.49	+3.1	9	5,033	n.	24	nw.	13	11	7	12	5.6	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations November, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							**43.1**	**−2.1**										**78**	**4.27**	**+1.1**										**6.9**		
Chattanooga	762	190	215	29.31	30.14	0.00	49.4	−1.0	75	1	55	11	30	44	25	45	40	74	11.60	+8.2	16	5,010	ne.	26	se.	10	8	5	17	6.7	2.4	0.0
Knoxville	995	102	111	29.06	30.13	.00	47.4	−0.5	79	1	54	8	30	41	28	44	41	82	8.55	+5.5	14	3,786	sw.	26	sw.	27	6	3	21	7.3	3.4	0.0
Memphis	399	76	97	29.71	30.14	+.02	48.0	−3.7	74	12	54	20	30	42	31	44	40	78	3.33	−0.9	14	4,652	sw.	24	n.	29	6	6	18	6.5	4.9	0.0
Nashville	546	168	191	29.57	30.16	+.04	46.8	−2.2	74	1	54	8	30	40	28	43	38	76	4.79	+1.3	10	5,355	nw.	29	s.	10	4	11	15	7.1	5.0	0.0
Lexington	989	193	230	29.04	30.14	+.02	41.8	−3.0	69	12	48	−3	30	35	23	------	------	------	3.92	+0.6	17	7,729	sw.	56	nw.	27	6	5	19	7.3	3.2	0.7
Louisville	525	188	234	29.55	30.15	+.03	42.8	−3.9	72	12	49	1	30	36	23	39	36	81	3.50	−0.1	13	6,280	n.	48	w.	27	6	8	16	6.9	2.1	1.0
Evansville	431	76	116	29.68	30.17	+.05	43.6	−3.0	70	12	50	4	30	37	23	39	35	76	2.38	−1.4	8	5,271	nw.	30	nw.	27	8	8	14	6.2	4.1	2.5
Indianapolis	822	194	230	29.21	30.12	+.02	39.2	−3.1	68	12	46	0	30	32	25	34	29	72	2.15	−1.2	10	6,891	w.	44	w.	27	9	6	15	6.3	0.3	0.1
Royal Center	736	11	55	29.30	30.12	------	35.2	------	56	1	42	−1	30	28	25	------	------	------	2.58	−0.1	9	6,447	w.	39	w.	27	9	7	14	6.3	1.5	0.6
Terre Haute	575	96	120	29.49	30.13	------	40.0	------	64	12	47	0	30	33	26	35	31	78	2.55	−0.8	8	5,564	nw.	35	w.	27	8	9	13	6.2	0.1	0.1
Cincinnati	627	11	51	29.43	30.13	+.01	40.8	−1.7	68	12	48	1	30	34	24	37	34	80	4.19	+1.3	16	4,975	sw.	31	sw.	27	9	5	16	6.5	0.8	T.
Columbus	822	179	222	29.21	30.11	.00	39.9	−2.0	67	1	46	1	30	34	22	36	34	82	3.72	+1.0	13	6,124	w.	37	nw.	27	7	6	17	6.7	T.	T.
Dayton	899	137	173	29.13	30.12	------	39.4	−2.6	67	1	46	0	30	33	24	36	33	81	2.97	+0.1	12	5,872	w.	30	nw.	27	8	6	16	6.6	0.7	0.2
Elkins	1,947	59	67	28.02	30.13	+.01	40.8	−0.5	75	1	49	−3	30	32	41	37	34	82	4.55	+1.8	17	3,738	w.	31	w.	28	4	3	23	8.3	8.0	3.0
Parkersburg	637	77	82	29.46	30.14	+.02	43.2	−0.6	76	1	50	4	30	36	29	38	35	79	4.16	+1.6	16	3,740	sw.	28	sw.	27	5	3	22	7.7	0.2	0.1
Pittsburgh	842	353	410	29.17	30.09	−.01	41.0	−2.2	76	1	48	1	30	34	24	37	32	75	3.38	+1.1	14	6,300	w.	34	w.	28	5	8	17	7.1	0.5	T.
Lower Lake Region							**38.2**	**−1.2**										**78**	**2.87**	**+0.1**										**7.4**		
Buffalo	767	247	280	29.16	30.00	−.05	38.5	−0.9	66	1	44	8	30	33	20	35	32	77	2.31	−0.7	16	13,493	w.	62	sw.	18	0	14	16	7.6	3.6	T.
Canton	448	10	61	29.48	29.97	------	35.0	+1.1	66	1	42	2	29	28	22	------	------	------	3.04	−0.1	16	7,180	sw.	37	w.	30	1	9	20	8.0	1.6	0.3
Ithaca	836	5	100	29.10	30.03	------	38.8	------	67	2	46	7	30	32	22	35	31	79	1.74	−0.6	13	5,928	s.	30	nw.	15	3	8	19	7.8	0.3	T.
Oswego	335	76	91	29.63	30.00	−.05	39.1	−0.2	66	2	45	10	30	34	21	36	31	75	3.37	0.0	20	6,998	s.	30	nw.	15	1	3	26	8.7	20.5	6.9
Rochester	523	86	102	29.44	30.03	−.02	38.8	+0.1	69	1	45	10	30	33	22	35	31	76	1.92	−0.6	16	6,301	sw.	38	w.	30	4	6	20	7.6	1.3	0.2
Syracuse	596	65	79	29.37	30.02	−.04	40.5	+1.8	69	2	46	11	29	35	20	------	------	------	2.20	−0.6	16	5,016	sw.	28	sw.	30	3	5	22	7.7	1.2	T.
Erie	714	130	166	29.25	30.04	−.02	39.2	−2.2	69	1	44	6	30	34	22	35	32	76	4.65	+1.4	17	10,062	w.	34	se.	10	1	6	23	8.6	13.8	2.2
Cleveland	762	267	337	29.22	30.06	−.01	39.4	−1.5	68	1	44	4	30	34	20	36	31	75	2.92	+0.3	14	9,666	sw.	42	sw.	28	5	4	21	7.5	6.9	5.0
Sandusky	629	5	67	29.38	30.08	.00	38.3	−2.8	68	1	44	3	30	32	22	------	------	------	2.74	+0.4	12	6,301	sw.	28	nw.	28	8	5	17	6.8	0.9	0.1
Toledo	628	208	243	29.38	30.09	+.02	37.6	−2.8	65	1	43	2	30	32	20	34	31	79	3.77	+1.4	16	9,088	sw.	35	sw.	26	10	7	13	6.0	0.9	T.
Fort Wayne	856	113	124	29.14	30.09	------	36.7	−3.9	65	1	43	0	30	31	21	33	30	82	2.61	−0.3	9	6,227	w.	25	sw.	26	8	9	13	6.4	2.2	1.1
Detroit	730	218	258	29.25	30.06	.00	36.9	−2.4	64	1	42	4	30	32	20	34	32	84	3.20	+0.8	11	7,644	w.	33	sw.	26	4	16	10	6.5	1.4	T.
Upper Lake Region							**32.4**	**−3.0**										**78**	**1.50**	**−0.9**										**6.9**		
Alpena	609	13	92	29.31	29.99	−.02	32.3	−2.1	58	1	38	−2	29	26	26	30	27	81	1.23	−1.4	18	7,470	sw.	37	nw.	15	3	9	18	7.6	13.2	2.7
Escanaba	612	54	60	29.32	30.00	−.03	29.7	−3.4	55	16	37	−1	28	23	37	26	22	76	0.51	−1.6	4	7,151	sw.	28	nw.	28	9	10	11	5.6	4.0	1.5
Grand Haven	632	54	89	29.34	30.04	.00	36.0	−2.5	54	1	41	7	29	31	24	33	30	77	1.21	−1.5	12	9,486	w.	47	w.	27	3	3	24	8.6	6.9	2.5
Grand Rapids	707	70	87	29.27	30.06	+.01	35.3	−3.1	61	1	41	6	29	30	24	32	28	78	1.29	−1.5	13	4,194	w.	19	nw.	27	4	3	23	8.2	9.1	3.2
Houghton	668	64	99	29.23	29.97	−.05	29.5	−2.5	56	9	35	−2	28	24	27	------	------	------	3.24	+0.2	19	7,467	w.	34	w.	30	1	6	23	8.5	22.4	12.8
Lansing	878	6	49	29.08	30.05	------	33.4	−4.1	63	1	40	6	29	27	30	31	30	92	1.42	−1.1	11	3,968	w.	22	nw.	27	7	10	13	6.5	2.4	0.2
Ludington	637	60	66	29.31	30.02	------	35.1	−2.3	52	17	40	7	29	30	25	32	28	77	0.66	−2.0	13	9,215	w.	42	sw.	25	4	8	18	7.3	5.4	0.4
Marquette	734	77	111	29.15	29.98	−.04	30.4	−2.9	58	9	36	0	28	24	30	26	22	75	1.38	−1.5	15	7,473	w.	34	sw.	16	2	9	19	8.1	8.5	5.6
Port Huron	638	70	120	29.32	30.03	−.02	36.0	−1.5	64	1	42	6	29	30	24	32	29	79	2.83	+0.4	10	7,971	w.	36	w.	30	1	19	10	6.4	0.3	T.
Sault Sainte Marie	614	11	52	29.25	29.96	−.05	30.4	−1.6	61	1	37	−12	29	24	33	28	26	85	3.92	+1.2	22	6,228	sw.	36	nw.	29	5	7	18	7.5	34.5	19.9
Chicago	673	7	131	29.35	30.10	+.03	36.3	−3.8	54	9	42	1	29	31	24	32	28	73	1.47	−0.9	7	7,085	sw.	28	ne.	13	11	4	15	6.0	0.1	0.0
Green Bay	617	109	141	29.35	30.03	−.01	30.4	−3.6	53	9	37	−5	29	24	36	27	22	71	0.53	−1.6	5	8,030	sw.	30	sw.	5	9	7	14	6.1	1.1	0.0
Milwaukee	681	125	221	29.31	30.06	+.01	33.8	−3.5	54	9	40	−4	29	27	30	30	25	72	0.78	−1.0	6	9,331	w.	36	sw.	25	12	7	11	5.2	0.1	0.0
Duluth	1,133	5	47	28.76	30.03	−.01	24.5	−5.5	57	16	32	−17	29	17	30	21	17	77	0.59	−0.9	9	9,597	nw.	39	nw.	30	10	8	12	5.4	4.7	3.0
North Dakota							**25.2**	**−1.6**										**83**	**0.58**	**−0.1**										**6.2**		
Moorhead	940	50	58	29.03	30.08	+.01	24.8	−2.3	52	15	33	−11	29	17	30	22	19	84	1.08	+0.2	11	6,232	n.	29	nw.	5	10	6	14	6.1	12.2	1.7
Bismarck	1,674	8	57	28.26	30.11	+.04	27.9	−0.6	56	15	37	−6	21	19	36	24	21	80	0.25	−0.3	10	6,626	nw.	32	nw.	18	8	9	13	6.0	2.7	1.0
Devils Lake	1,478	11	44	28.43	30.07	+.01	20.8	−3.7	43	15	28	−12	29	13	31	19	18	90	0.78	+0.1	9	7,009	nw.	37	n.	18	6	10	14	6.7	11.2	5.1
Ellendale	1,457	10	56	28.49	30.10	------	25.8	------	50	16	34	−6	22	18	39	------	------	------	0.21	−0.5	8	9,891	nw.	50	n.	18	6	12	12	6.4	2.7	1.5
Grand Forks	833	12	67	------	------	------	23.0	------	52	15	31	−15	20	15	28	20	------	------	0.75	------	11	------	nw.	------	s.	22	11	11	8	------	6.9	3.7
Williston	1,878	41	48	28.07	30.12	+.06	27.4	+0.2	61	15	37	−12	21	18	33	24	21	79	0.50	0.0	11	5,947	nw.	28	nw.	27	8	9	13	5.9	4.9	2.2
Upper Mississippi Valley							**34.5**	**−4.0**										**77**	**1.16**	**−0.8**										**5.7**		
Minneapolis	918	102	208	29.05	30.07	------	29.0	−3.4	55	9	36	−7	29	22	27	------	------	------	0.36	−0.9	9	7,725	nw.	33	nw.	27	7	8	15	6.5	2.7	T.
St. Paul	837	236	261	29.13	30.07	+.01	28.2	−4.3	55	16	35	−7	29	21	28	------	------	------	0.32	−1.0	9	8,158	sw.	35	s.	22	6	12	12	6.1	2.8	T.
La Crosse	714	11	48	29.29	30.09	+.02	30.8	−4.4	56	2	39	−5	29	23	34	27	24	80	0.64	−0.9	9	3,224	nw.	16	nw.	27	9	8	13	5.9	1.6	T.
Madison	974	70	78	29.00	30.09	+.03	31.0	−4.2	52	2	38	−4	29	24	30	28	24	78	0.58	−1.2	4	6,447	w.	26	ne.	13	11	9	10	5.2	0.8	0.0
Wausau	1,247	4	64	------	30.05	------	27.6	------	53	9	35	−11	29	20	33	------	------	------	0.63	−1.2	7	4,505	w.	20	w.	22	9	4	17	------	1.8	1.0
Charles City	1,015	10	51	29.01	30.12	+.04	29.2	−3.8	54	2	37	−7	29	21	30	26	23	83	1.11	−0.4	8	4,303	nw.	22	nw.	27	10	9	11	5.3	1.2	0.2
Davenport	606	71	79	29.44	30.12	+.04	34.6	−4.4	58	11	42	−3	29	27	28	31	27	77	1.51	−0.3	9	6,814	nw.	33	nw.	27	12	6	12	5.4	1.5	0.7
Des Moines	861	84	97	29.20	30.14	+.06	33.8	−4.6	58	11	42	0	29	25	28	30	26	78	1.87	+0.4	9	6,767	n.	40	nw.	27	10	13	7	5.0	1.5	0.8
Dubuque	700	81	96	29.33	30.11	+.04	32.3	−4.7	57	11	40	−4	30	24	34	29	25	75	0.68	−1.0	8	4,419	nw.	22	nw.	27	10	8	12	5.8	0.7	0.3
Keokuk	614	64	78	29.46	30.16	+.07	36.6	−4.5	60	11	44	2	29	29	27	32	27	72	1.51	−0.4	6	5,183	sw.	37	w.	27	12	4	14	5.7	0.4	0.2
Cairo	358	87	93	29.76	30.15	+.03	44.6	−2.7	72	10	52	9	30	38	23	40	35	76	2.51	−1.2	6	5,537	n.	25	n.	28	7	6	17	6.8	T.	0.0
Peoria	609	11	45	29.46	30.14	+.05	35.8	−1.7	57	11	44	−1	30	28	29	32	28	82	1.72	−0.6	7	4,420	nw.	25	w.	27	13	6	11	4.7	0.2	0.2
Springfield, Ill	636	154	191	29.44	30.13	+.03	37.2	−5.0	61	11	44	0	30	30	23	34	31	82	1.17	−1.4	7	7,785	w.	38	nw.	27	10	3	17	6.0	0.3	T.
Hannibal	534	74	109	29.56	30.15	+.06	37.8	−4.3	62	11	46	−1	30	30	28	------	------	------	1.43	−0.6	5	5,700	sw.	28	nw.	27	9	10	11	5.6	2.0	1.0
St. Louis	568	265	303	29.52	30.14	+.04	41.5	−3.6	69	12	48	3	30	35	23	36	30	69	1.41	−1.4	5	6,981	nw.	37	nw.	27	9	9	12	5.7	6.5	5.4
Missouri Valley							**34.5**	**−4.5**										**76**	**0.94**	**−0.4**										**5.8**		
Columbia, Mo	784	6	84	29.29	30.15	+.06	38.1	−5.2	68	11	46	−3	30	30	37	------	------	------	1.23	−1.0	6	5,088	nw.	34	w.	27	9	7	14	5.0	3.0	2.0
Kansas City	963	161	181	29.10	30.16	+.07	38.6	−5.1	64	11	46	11	22	32	25	34	29	73	1.09	−0.7	7	6,921	nw.	35	nw.	27	9	9	12	5.6	0.1	0.0
St. Joseph	967	11	49	29.09	30.16	------	36.1	------	64	11	44	10	22	28	29	32	28	76	1.62	0.0	6	5,355	nw.	35	nw.	27	10	7	13	5.6	3.2	2.2
Springfield, Mo	1,324	98	104	28.73	30.17	+.07	39.7	−6.0	67	11	47	14	22	33	26	35	31	75	1.10	−1.7	7	6,075	nw.	27	se.	9	7	8	15	6.3	T.	0.0
Iola	984	11	50	29.09	30.17	+.08	38.6	−5.5	70	11	47	8	22	30	34	------	------	------	1.16	−0.7	10	3,827	n.	19	nw.	18	8	6	16	6.6	0.2	0.0
Topeka	987	92	107	------	------	------	37.5	−5.3	63	11	45	10	22	30	28	------	------	------	0.56	−1.0	6	6,031	sw.	31	nw.	27	11	8	11	5.4	1.0	T.
Lincoln	1,189	11	81	28.86	30.18	+.10	34.3	−4.8	57	5	42	1	22	26	28	30	26	77	1.04	0.0	8	6,483	n.	37	nw.	18	10	9	11	6.0	2.7	T.
Omaha	1,105	115	122	28.95	30.17	+.09	33.8	−4.7	56	2	42	3	29	26	29	30	25	72	1.38	+0.3	8	5,727	nw.	30	nw.	27	12	13	5	4.5	8.5	2.6
Valentine	2,598	47	54	27.38	30.20	+.12	29.6	−5.0	58	15	40	1	21	20	33	26	22	79	1.37	+0.8	10	5,722	w.	36	nw.	18	6	11	13	6.0	15.0	0.6
Sioux City	1,135	94	164	28.91	30.17	+.09	31.8	−3.4	55	10	40	1	22	24	29	28	24	76	0.41	−0.6	7	7,710	nw.	44	nw.	27	5	14	11	6.0	2.4	1.3
Huron	1,306	59	74	28.71	30.15	+.07	28.7	−2.8	60	16	38	−7	22	20	44	26	22	79	0.36	−0.2	8	6,501	w.	31	nw.	18	9	7	14	6.4	3.0	0.5
Pierre	1,572	70	75	28.44	30.16	+.08	31.4	−2.2	61	17	40	−4	21	23	38	27	23	74	0.58	+0.1	10	5,653	nw.	36	nw.	18	12	7	11	5.5	6.1	2.6
Yankton	1,233	49	57	28.80	30.17	+.00	31.5	−3.8	56	26	40	−1	29	23	30	------	------	------	0.33	−0.5	6	5,454	nw.	29	nw.	18	8	9	13	6.1	2.2	1.5

Table 1.—*Climatological data for Weather Bureau stations November, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles								0-10	In.	In.
Northern Slope							29.1	−3.7										72	0.87	+0.1										5.9		
Billings	3,140	5					30.8		59	27	42	−16	21	20	33				0.77		10		nw.				13	8	9		7.1	
Havre	2,505	11	44	27.48	30.18	+0.15	33.0	+1.8	62	9	42	−10	21	24	38	28	22	67	0.29	−0.3	5	6,096	sw.	35	sw.	15	6	12	12	6.3	2.8	T.
Helena	4,110	87	112	25.95	30.28	+.18	31.6	−1.6	58	4	40	−7	21	23	31	27	21	66	0.38	−0.4	6	5,237	sw.	36	sw.	17	7	5	18	6.5	4.6	0.3
Kalispell	2,973	48	56	27.13	30.29	+.22	31.0	−1.4	53	16	40	−1	21	22	26	27	22	71	0.17	−1.3	2	2,826	nw.	18	ne.	28	8	7	15	6.4	1.5	0.0
Miles City	2,371	48	55	27.59	30.23	+.16	31.8	+0.9	62	15	41	−4	21	23	32	28	23	73	0.49	−0.1	8	4,519	s.	26	nw.	17	8	6	16	6.7	3.9	1.0
Rapid City	3,259	50	58	26.70	30.24	+.16	32.1	−3.8	68	15	42	−4	21	22	43	27	20	65	0.71	+0.2	8	5,566	n.	35	nw.	17	8	12	10	5.9	10.1	3.2
Cheyenne	6,088	84	101	24.04	30.23	+.16	26.8	−8.0	55	17	36	−4	21	17	36	22	16	66	1.53	+1.0	11	8,974	w.	42	w.	28	11	8	11	5.2	15.0	1.5
Lander	5,372	60	68	24.74	30.35	+.25	19.0	−11.3	58	17	32	−15	20	6	47	17	15	88	1.45	+0.8	8	2,071	sw.	38	ne.	30	13	9	8	4.5	13.0	2.5
Sheridan	3,790	10	47	26.21	30.26		27.2		62	9	40	−15	21	14	44	23	19	78	2.32	+1.7	12	3,016	nw.	22	nw.	30	7	11	12	5.9	19.3	3.0
Yellowstone Park	6,241	11	48	24.00	30.36	+.25	23.2	−6.1	45	16	33	−12	21	13	28	20	15	73	0.86	−0.4	9	4,306	sw.	26	n.	10	8	5	17	6.7	9.8	1.6
North Platte	2,821	11	51	27.17	30.20	+.12	33.0	−3.6	60	10	44	2	22	22	38	27	22	75	0.48	0.0	7	5,156	n.	26	n.	18	13	10	7	4.8	3.7	0.0
Middle Slope							35.6	−7.2										74	1.59	+0.4										5.4		
Denver	5,292	106	113	24.80	30.23	+.17	31.6	−8.2	67	17	43	0	21	20	40	26	19	63	1.32	+0.8	12	4,815	s.	32	n.	30	12	15	3	4.1	23.1	0.1
Pueblo	4,685	80	86	25.34	30.16	+.11	32.8	−6.6	68	17	45	−1	24	21	41	27	20	64	1.14	+0.8	9	3,591	nw.	24	w.	17	11	11	8	4.9	14.6	0.0
Concordia	1,392	50	58	28.69	30.21	+.13	35.2	−6.4	58	5	43	−4	22	27	29	31	27	79	1.42	+0.4	9	4,979	nw.	27	nw.	18	10	8	12	5.6	6.7	0.0
Dodge City	2,509	11	51	27.54	30.23	+.16	34.0	−8.6	68	5	43	1	22	25	37	30	27	81	2.53	+1.8	8	5,544	nw.	26	ne.	21	15	4	11	4.6	16.8	T.
Wichita	1,358	139	158	28.69	30.16	+.08	38.0	−6.8	61	11	45	8	22	31	25	34	31	77	1.59	+0.2	10	6,942	n.	35	s.	30	11	6	13	5.8	1.2	0.0
Broken Arrow	765	11	56	29.32	30.17		42.4		71	11	50	16	22	34	30				1.39	−1.4	8	7,040	n.	26	n.	29	6	10	14	6.7	T.	0.0
Oklahoma City	1,214	10	47	28.86	30.18	+.10	42.4	−6.4	72	11	50	20	22	34	28	37	34	81	1.74	−0.1	9	5,590	n.	24	n.	12	9	9	12	6.0	0.4	0.0
Southern Slope							44.7	−7.0										68	0.64	−0.4										4.4		
Abilene	1,738	10	52	28.31	30.16	+.00	47.2	−6.3	80	28	57	28	22	38	44	39	34	68	0.50	−0.8	7	5,541	s.	30	s.	30	14	7	9	4.7	T.	0.0
Amarillo	3,676	10	49	26.35	30.17	+.12	37.4	−8.1	70	5	47	7	22	28	35	32	27	73	0.91	0.0	9	5,763	n.	22	sw.	30	13	4	13	4.9	6.9	0.0
Del Rio	944	64	71	29.11	30.12	+.07	53.9	−6.1	81	11	65	29	16	43	39	45	37	61	0.08	−1.2	4	5,403	se.	31	nw.	12	13	10	7	4.6	0.0	0.0
Roswell	3,566	75	85	26.46	30.16	+.13	40.6	−7.5	78	28	54	16	22	27	50	34	29	72	1.09	+0.2	5	4,477	ne.	33	ne.	19	19	5	6	3.4	7.6	0.0
Southern Plateau							47.9	−1.4										50	0.27	−0.2										1.6		
El Paso	3,778	152	175	26.27	30.12	+.12	47.0	−5.7	72	19	59	24	14	35	35	38	29	56	0.33	−0.2	3	6,400	e.	31	ne.	12	24	4	2	1.8	0.4	0.0
Santa Fe	7,013	38	53	23.27	30.16	+.13	32.6	−6.3	58	5	43	8	13	22	29	26	21	70	0.89	+0.2	2	3,784	n.	20	n.	14	18	8	4	3.1	8.3	0.0
Flagstaff	6,907	10	59	23.39	30.08	+.06	36.9	+2.3	67	19	54	8	25	20	48	27		57	0.08		2		e.		ne.	13	22	7	1		T.	0.0
Phoenix	1,108	10	107	28.86	30.03	+.05	57.9	−1.8	87	3	74	32	14	42	44	43	27	36	0.11	−0.6	1	2,520	e.	19	n.	7	25	5	0	1.0	0.0	0.0
Yuma	141	9	54	29.88	30.03	+.05	60.6	−1.8	87	4	76	35	25	45	38	45	26	32	T.	−0.3	0	3,144	n.	28	nw.	12	28	2	0	0.4	0.0	0.0
Independence	3,957	6	27	26.11	30.18	+.13	52.2	+5.3	80	2	70	26	25	35	43	35			0.00	−0.3	0		nw.				29	1	0		0.0	0.0
Middle Plateau							37.3	−1.9										47	0.17	−0.6										2.0		
Reno	4,532	74	81	25.66	30.29	+.18	41.8	+0.8	73	5	60	14	22	24	43	32	21	47	0.00	−0.6	0	2,719	sw.	30	w.	10	28	2	0	0.9	0.0	0.0
Tonopah	6,090	12	20				42.6		60	3	51	18	12	34	24	32	16	32	0.00		0		w.									
Winnemucca	4,344	18	56	25.83	30.34	+.20	36.0	−2.4	68	4	56	4	12	16	51	26	14	45	0.00	−0.7	0	3,697	ne.	22	nw.	6	27	3	0	1.5	0.0	0.0
Modena	5,473	10	43	24.74	30.20	+.12	35.5	−0.9	68	18	54	1	22	17	48	25	9	40	0.00	−0.6	0	5,244	w.	36	n.	6	27	3	0	0.9	0.0	0.0
Salt Lake City	4,360	163	203	25.80	30.26	+.14	38.4	−2.7	60	5	47	20	22	30	27	32	24	56	0.12	−1.2	2	3,283	nw.	32	nw.	10	17	9	4	3.4	T.	0.0
Grand Junction	4,602	60	68	25.52	30.19	+.11	35.0	−4.3	58	5	46	13	22	23	35	28	20	60	0.74	+0.2	4	2,696	se.	14	se.	2	17	9	4	3.3	4.9	0.0
Northern Plateau							36.0	−3.4										63	0.13	−1.4										4.5		
Baker	3,471	48	53	26.69	30.38	+.22	33.8	−2.2	60	1	48	6	20	20	38	28	21	62	0.10	−1.0	3	3,702	se.	17	n.	6	13	13	4	3.9	0.7	0.0
Boise	2,739	78	86	27.42	30.36	+.19	37.6	−3.4	59	2	50	15	21	26	30	31	20	52	0.13	−1.2	2	2,046	se.	21	nw.	6	14	12	4	4.0	T.	0.0
Lewiston	757	40	48	29.53	30.37	+.25	37.2	−4.2	61	2	48	12	21	26	31				T.	−1.6	0	1,023	w.	20	nw.	17	8	15	7	5.6	0.0	0.0
Pocatello	4,477	60	68	25.65	30.30	+.16	34.2	−2.5	63	5	46	8	21	23	37	28	21	62	0.46	−0.4	4	4,383	se.	33	sw.	2	14	11	5	4.0	2.0	0.0
Spokane	1,929	101	110	28.24	30.36	+.26	33.3	−5.2	55	2	43	10	23	24	25	30	25	72	T.	−2.1	0	1,665	nw.	19	sw.	16	9	16	5	5.1	0.0	0.0
Walla Walla	991	57	65	29.24	30.34	+.21	40.2	−2.6	65	1	49	17	20	31	30	35	29	66	0.11	−1.9	3	1,932	s.	12	s.	16	13	12	5	4.4	0.0	0.0
North Pacific Coast Region							45.4	−0.8										78	1.37	−4.9										6.1		
North Head	211	11	56	30.07	30.31	+.26	47.8	−0.4	67	3	53	36	20	43	20	45	41	82	1.56	−6.9	9	5,828	n.	52	s.	16	13	8	9	5.1	0.9	0.0
Port Angeles	29	8	53		30.33		42.7		56	2	49	29	21	37	19				1.30	−2.7	7	2,435	s.	22	n.	16	3	11	16		0.0	0.0
Seattle	125	215	250	30.18	30.32	+.28	45.2	−0.4	57	14	50	34	24	40	17	43	40	82	1.23	−3.8	8	3,545	ne.	35	sw.	16	2	12	16	7.2	0.0	0.0
Tacoma	194	172	201	30.10	30.32	+.28	46.2	+1.6	60	14	53	27	21	40	20				1.00	−5.3	9	3,429	n.	37	sw.	16	1	13	16	7.9	0.0	0.0
Tatoosh Island	86	9	53	30.20	30.30	+.33	46.3	+0.4	55	4	49	40	20	44	12	45	44	94	4.96	−7.0	11	9,228	e.	38	e.	3	5	8	17	7.1	0.0	0.0
Yakima	1,076	58	67	29.16	30.34		37.8		66	2	50	18	21	26	33	32	24	61	T.	−0.8	0	1,672	se.	21	nw.	9	9	13	8	5.0	T.	0.0
Medford	1,425	4	80	28.72	30.27		42.2		80	3	60	16	21	25	48	37	30	67	0.02		2		s.	16	se.	12	19	9	2	3.0	0.0	0.0
Portland, Oreg	153	68	106	30.15	30.32	+.22	44.8	−2.0	67	3	52	30	16	38	26	41	37	78	0.67	−5.4	6	2,642	nw.	17	sw.	16	4	12	14	6.9	0.0	0.0
Roseburg	510	75	99	29.73	30.30	+.18	41.8	−4.1	66	1	52	25	14	32	33	40	36	82	0.25	−4.4	2	1,640	nw.	13	n.	6	4	16	10	6.3	0.0	0.0
Middle Pacific Coast Region							55.1	+1.2										54	T.	−2.8										2.3		
Eureka	62	73	89	30.12	30.19	+.08	47.5	−3.6	77	3	55	32	19	40	30	45	43	85	T.	−5.2	0	2,182	se.	24	n.	11	5	6	19	7.3	0.0	0.0
Red Bluff	330	5	58	29.77	30.13	+.02	57.8	+4.0	88	2	74	34	14	42	43	43	25	32	0.00	−3.0	0	3,559	nw.	23	nw.	6	26	4	0	1.3	0.0	0.0
Sacramento	69	106	117	30.04	30.10	+.01	56.3	+2.7	82	3	71	37	14	42	34	46	32	44	0.00	−1.9	0	3,261	nw.	24	nw.	11	30	0	0	0.5	0.0	0.0
San Francisco	155	208	243	29.93	30.10	+.01	59.7	+3.4	82	3	69	46	14	51	26	50	41	57	0.00	−2.4	0	2,829	n.	23	w.	10	26	3	1	1.4	0.0	0.0
San Jose	141	12	110	29.95	30.10		54.1	−0.3	84	3	70	33	14	38	41				0.00	−1.5	0	2,757	s.	17	nw.	10	25	4	1	1.1	0.0	0.0
South Pacific Coast Region							61.7	+3.4										43	T.	−1.0										0.7		
Fresno	327	89	98	29.76	30.12	+.06	57.1	+2.9	86	4	72	36	11	42	37	44	26	32	0.00	−0.9	0	2,222	nw.	16	nw.	10	30	0	0	0.2	0.0	0.0
Los Angeles	338	159	191	29.69	30.05	+.03	65.8	+4.9	90	4	77	44	21	54	30	50	37	42	0.00	−1.2	0	2,984	ne.	12	w.	27	28	2	0	0.7	0.0	0.0
San Diego	87	62	70	29.93	30.02	.00	62.1	+2.4	87	2	73	45	22	52	35	52	42	56	T.	−0.8	0	2,862	nw.	23	ne.	12	26	4	0	1.2	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.85	29.94		77.7	−0.7	85	30	82	69	16	73	15				3.62	−3.3	18	8,329	e.	33	e.	2	6	20	4	5.2	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	[1] 29.70	[1] 29.78	−.03	79.6	+0.5	91	26	86	70	18	74	18			[2] 88	12.62	+2.3	16	3,518	nw.	19	nw.	20	1	6	23	8.1	0.0	0.0
Cristobal	38	7	97	[1] 29.77	[2] 29.79	−.04	81.7	+2.4	92	2	87	73	1	76	18	76	75	[2] 83	8.90	−12.2	20	5,918	n.	23	n.	26	2	9	19	7.6	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[1] 29.30	[1] 29.86		9.4		38	25	18	−18	18	0	31	9	6	84	0.48		11		n.				5	9	16	6/9	7.7	9.2
Juneau	80	11	50	[1] 29.95	[1] 30.04		39.0		50	28	43	26	19	35	15	38	36	90	17.56		27	5,128	se.	40	e.	14	1	3	26	9.2	T.	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1] 29.87	[1] 29.91		74.3		84	7	79	63	24	69	16	68	64	74	4.94	+1.1	16	5,361	ne.	30	w.	25	7	11	12	6.1	0.0	.00

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken bihourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, November, 1929*

Stations	Altitude above mean sea level Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				38.0		45.0	31.1	55	18	7.23		0.5
Sydney, C. B. I.	48	29.92	29.97	+0.02	36.6	−0.5	42.1	31.0	56	12	4.95	−0.49	6.5
Halifax, N. S.	88	29.90	30.01	.00	38.9	+1.6	45.9	32.0	55	9	5.82	+0.16	2.6
Yarmouth, N. S.	65	29.88	29.95	−.07	39.2	−0.7	45.1	33.2	54	19	4.67	+0.18	5.4
Charlottetown, P. E. I.	38												
Chatham, N. B.	28	29.84	29.87	−.10	30.4	−0.6	37.9	22.9	58	0	2.05	−1.70	3.1
Father Point, Que.	20	29.90	29.92	−.04	29.3	+0.4	36.0	22.6	58	2	2.85	−0.26	18.9
Quebec, Que.	296	29.64	29.98	−.04	30.1	+1.1	35.7	24.5	61	0	3.71	−0.05	16.5
Doucet, Que.	1,236				23.8		29.7	17.9	58	0	0.95		3.1
Montreal, Que.	187	29.75	29.96	−.07	35.0	+3.2	40.7	20.3	61	3	3.70	−0.04	3.8
Ottawa, Ont.	236	29.71	29.98	−.04	34.0	+2.3	41.1	26.9	63	−3	2.65	+0.11	3.9
Kingston, Ont.	285	29.68	30.00	−.04	37.3	+2.3	42.4	32.2	60	4	2.47	−0.77	0.3
Toronto, Ont.	379	29.59	30.01	−.03	37.8	+2.2	43.3	32.4	61	6	3.47	+0.33	1.1
Cochrane, Ont.	930				20.8		26.1	15.5	57	−15	1.75		11.1
White River, Ont.	1,244	28.55	29.90	−.08	19.0	−1.5	26.4	11.7	47	−25	1.35	−0.50	8.1
London, Ont.	808				34.9		40.7	29.2	62	4	4.59		1.9
Southampton, Ont.	656	29.25	29.98	−.04	34.9	−0.1	40.4	29.3	65	0	4.84	+1.14	25.2
Parry Sound, Ont.	688	29.25	29.96	−.05	32.2	+0.1	37.8	26.7	61	−13	4.72	+0.35	28.3
Port Arthur, Ont.	644	29.24	29.97	−.03	25.0	+1.0	31.1	19.0	57	−12	2.57	+1.24	5.1
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.15	30.04	.00	18.6	+1.3	25.6	11.6	44	−19	0.62	−0.38	6.2
Le Pas, Man.	860				17.5		23.9	11.2	46	−17	0.98		6.9
Qu'Appelle, Sask.	2,115	27.73	30.06	+.06	21.8	+3.0	29.7	14.0	44	−15	1.23	+0.34	12.1
Moose Jaw, Sask.	1,759				26.9		35.4	18.4	58	−16	0.68		3.7
Swift Current, Sask.	2,392	27.46	30.06	+.04	28.1	+4.9	37.2	19.1	60	−16	0.98	+0.29	7.7
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.44	30.06	+.03	24.0	+8.6	31.7	16.2	59	−12	0.84	+0.01	8.3
Battleford, Sask.	1,592	28.27	30.07	+.05	27.9	+11.6	37.8	18.1	62	−16	0.58	0.00	4.6
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	30.06	30.32	+.33	44.8	+1.6	48.7	40.9	55	35	1.91	−5.06	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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Stations	Altitude above mean sea level Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
Father Point, Que.	20	29.89	29.91	−0.04	40.5	+0.7	46.1	34.9	57	28	3.14	+0.24	0.0
Montreal, Que.	187	29.78	29.99	−.02	47.1	+2.3	54.0	40.3	72	30	4.01	+0.88	0.3
Winnipeg, Man.	760	29.22	30.06	+.08	45.6	+6.5	55.2	36.1	78	19	0.90	−0.80	4.0
Medicine Hat, Alb.	2,144	27.68	29.95	−.02	48.7	+3.9	62.3	35.1	82	22	0.19	−0.39	1.2
Calgary, Alb.	3,428	26.44	30.03	+.08	45.3	+5.2	59.6	31.1	80	9	1.36	+0.88	7.8
Banff, Alb.	4,521	25.45	30.06	+.11	41.5	+2.2	52.8	30.3	66	12	0.95	−0.07	2.2
Edmonton, Alb.	2,150	27.65	29.94	+.01	45.5	+4.4	60.4	30.7	80	15	0.14	−0.56	0.0
Kamloops, B. C.	1,262	28.78	30.09	+.13	48.8	+1.8	58.1	39.6	75	25	0.74	+0.13	0.0
Estevan Point, B. C.	20				50.0		55.7	44.3	60	34	14.29		0.0
Prince Rupert, B. C.	170				49.5		53.5	45.5	62	36	12.24		0.0
Hamilton, Ber.	151	29.97	30.13	+.11	74.4	+1.4	79.7	69.2	88	65	5.97	−0.74	0.0

Chart I. Departure (°F.) of the Mean Temperature from the Normal, November, 1929

Chart II. Tracks of Centers of Anticyclones, November, 1929. (Inset) Departure of Monthly Mean Pressure from Normal
(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, November, 1929. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by Wilfred P. Day)

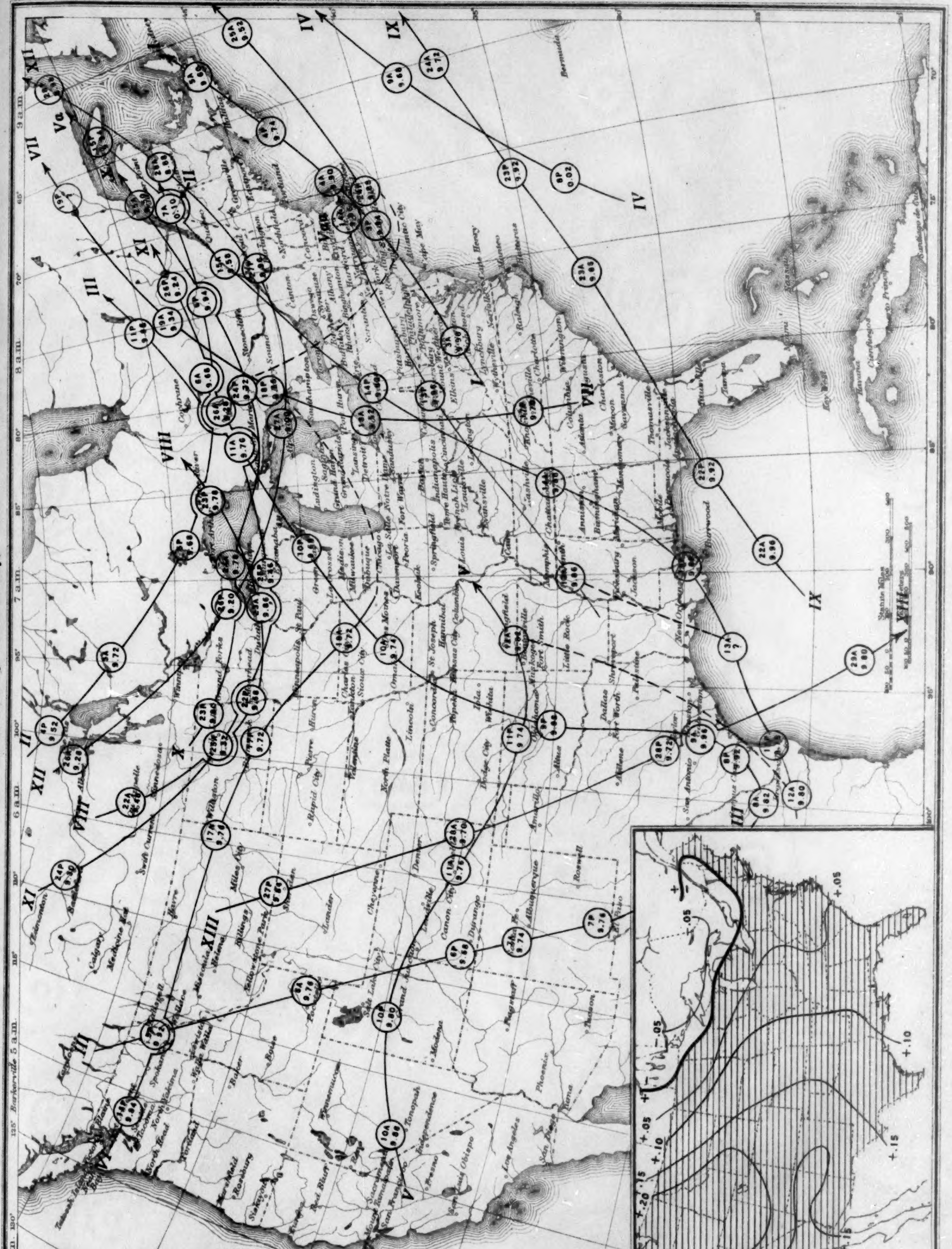


Chart III. Tracks of Centers of Cyclones, November, 1929. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by Wilfred P. Day)

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, November, 1929

Chart V. Total Precipitation, Inches, November, 1929. (Inset) Departure of Precipitation from Normal.

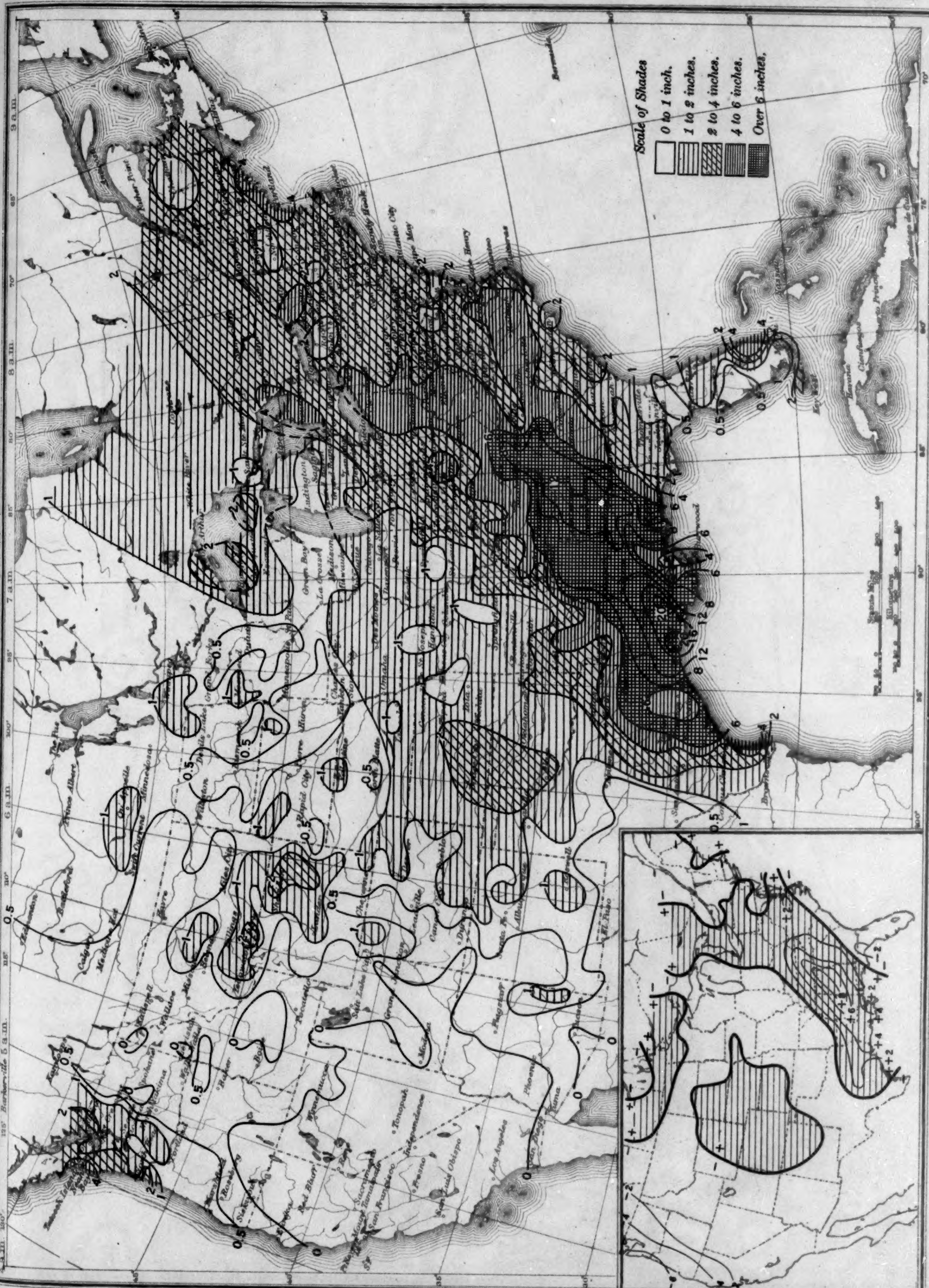


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, November, 1929

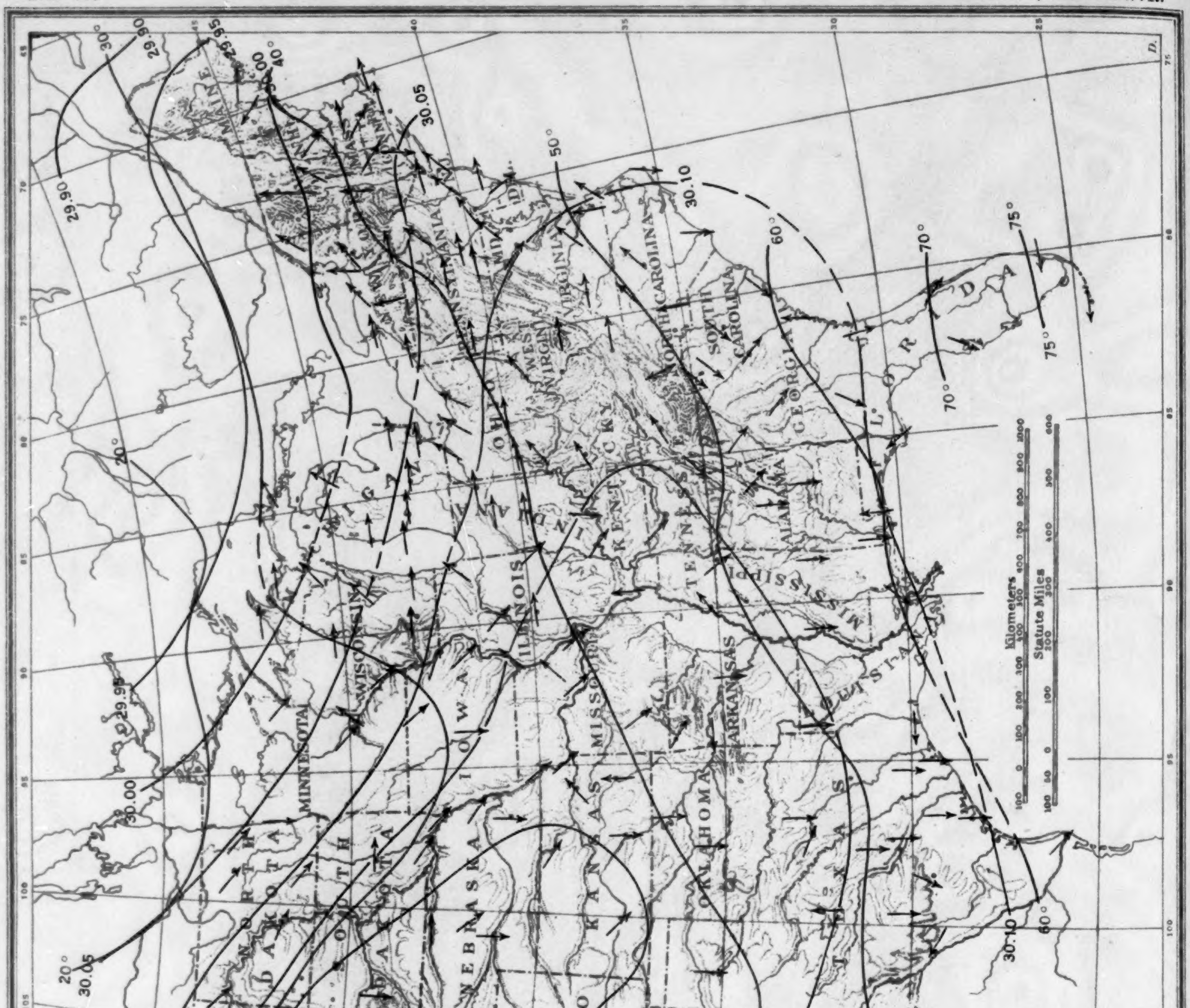
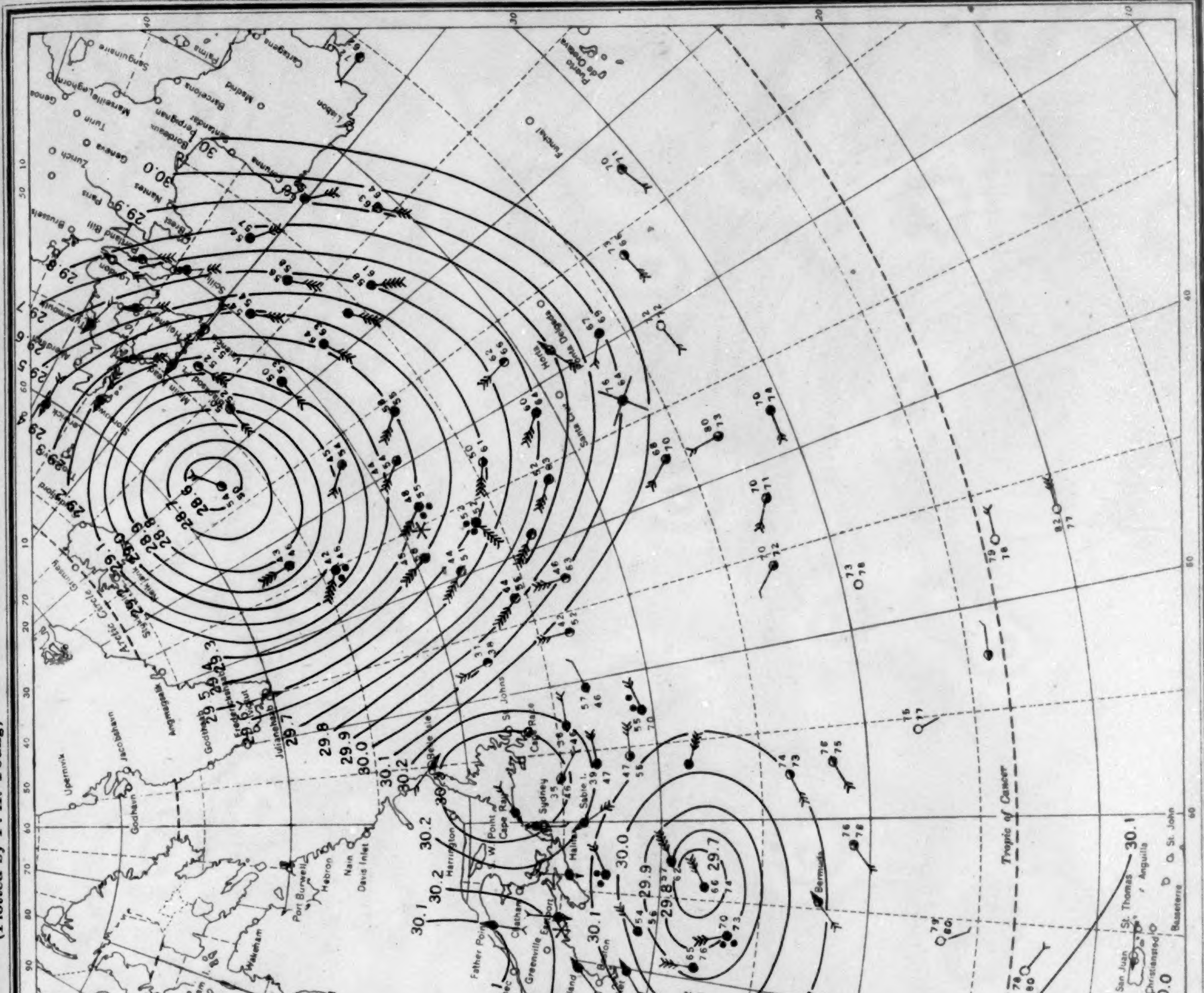


Chart VII. Total Snowfall, Inches, November, 1929.

Chart VIII. Weather Map of North Atlantic Ocean, November 24, 1929
(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, November 24, 1929
(Plotted by F. A. Young)



Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◐ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart IX, Weather Map of North Atlantic Ocean, November 25, 1929

(Plotted by F. A. Young)

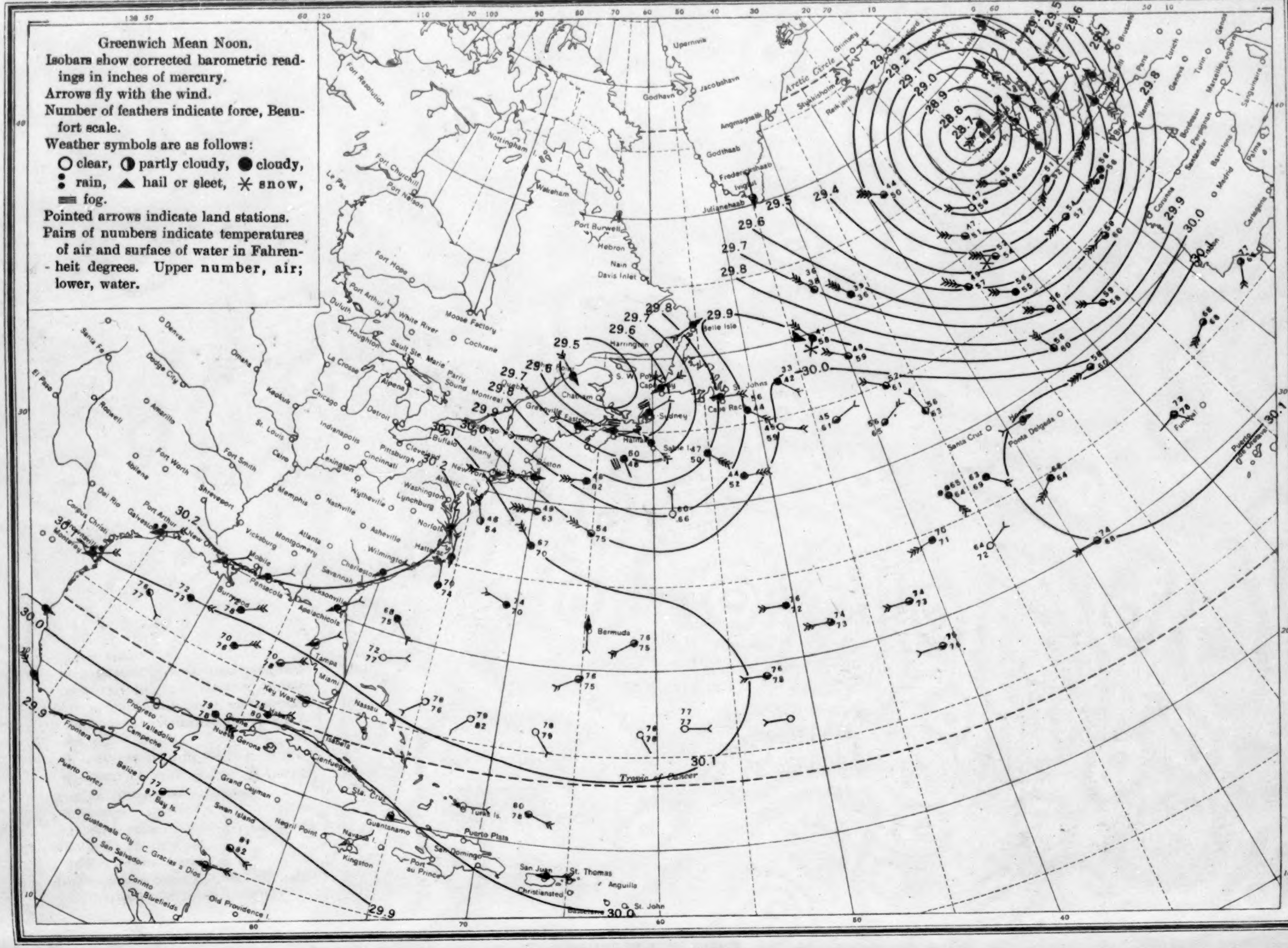


Chart X. Weather Map of North Atlantic Ocean, November 26, 1929

(Plotted by F. A. Young)

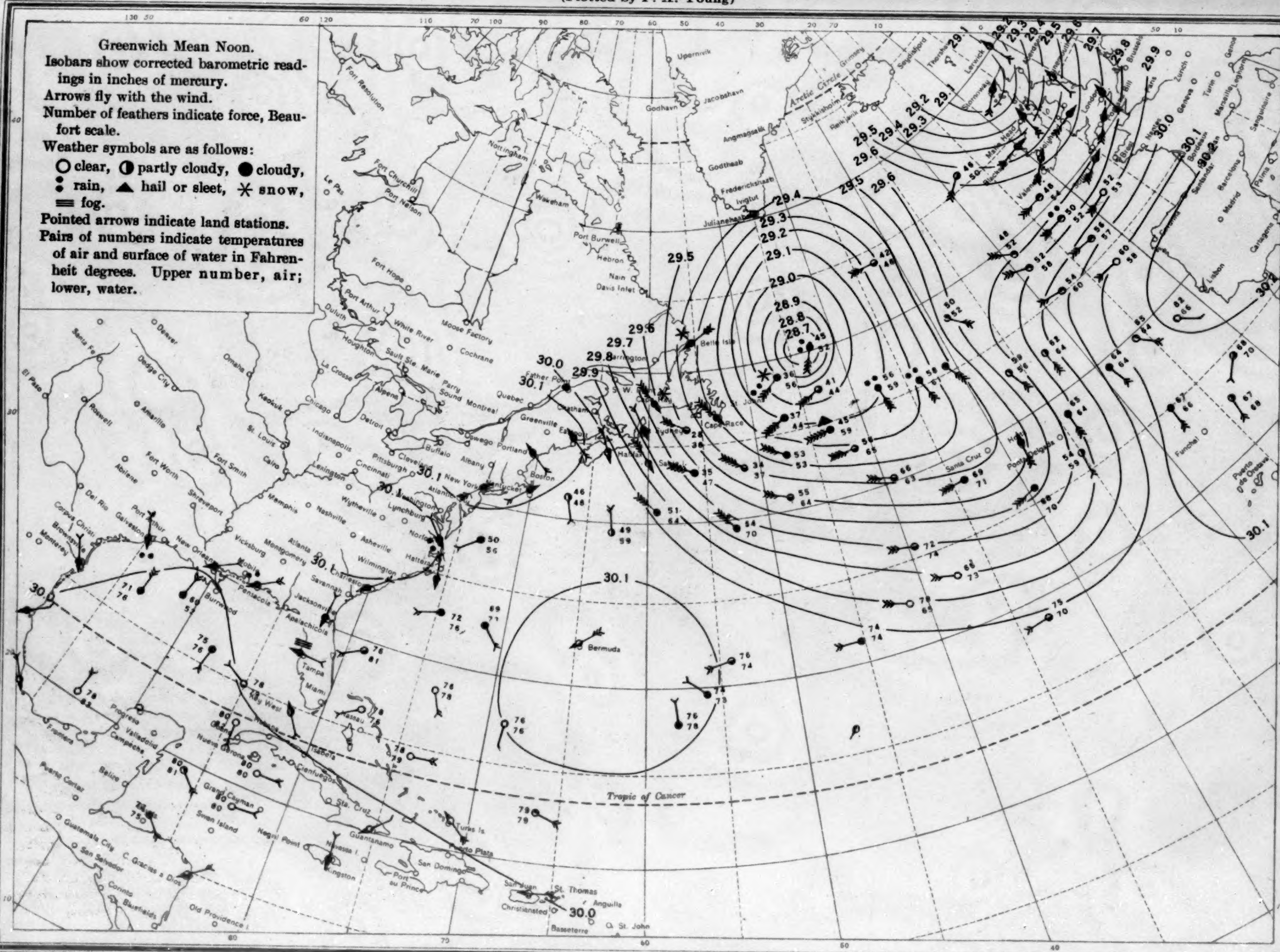


Chart XI. Weather Map of North Atlantic Ocean, November 27, 1929
(Plotted by F. A. Young)